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GENERAL ASTRONOMY.

NEW SERIES, No. 1. JANUARY, 1892. WHOLE No. 101.

THE EFFECT OF PRESSURE UPON THE TRANSMISSION OF RADIANT ENERGY THROUGH GASEOUS MEDIA.

SEVERINUS J. CORRIGAN.

FOR GENERAL ASTRONOMY.

While pursuing, recently, an investigation having for its object the determination of the absolute quantity of energy radiated, in unit time, from the filament of an incandescent electric lamp of a given candle power, I found that certain facts anent the *modus operandi* of "radiation" and the laws governing it, were disclosed thereby. So far as I know, they have not been noticed heretofore, and as they have a bearing upon important astronomical questions, I have thought that a publication of the results of this investigation would fall within the scope of ASTRONOMY AND ASTRO-PHYSICS, and prove of interest to some of its readers.

The following is a statement of the problem that presented itself for solution:

By what amount will the absolute quantity of energy radiated in unit time from a body of given surface, heated to a given degree of temperature while enclosed in a vessel containing atmospheric air or other gases at a given pressure, be changed by variation of the pressure or the density of the enclosed gas?

In attacking this problem my first step was to frame a hypothesis as to the nature and cause of the pressure of a gas against the walls of a containing vessel. I assumed, and this assumption is sanctioned by most eminent authority in "Molecular Physics," that this pressure is due to the impact of the minute particles of which the gas is composed, upon the enclosing walls, this impact being caused by the incessant and almost inconceivably rapid vibration of these particles. It is also assumed, and I purpose to prove the validity of this assumption by the agreement between theory and observation or the results of experiment, that the total pressure against the envelope, which pressure will be designated by P, is proportional to the product of the mass, M, of the enclosed gas into the number of vibrations made in unit time, which number will be designated by n. It is obvious that the pressure, or in other words, the result of impact

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will be greater or less as the number of particles of equal mass, m, and also the number of vibrations in unit time are greater or less; thus one particle vibrating twice in unit time will produce the same effect as two particles vibrating only once in the same time. This fact is expressed by the equation $P = Mn$ (1). It must be borne in mind that in this equation and also in those which are to follow, only relative values are considered.

From the well known definition of density, it is plain that the mass, M, of the gas contained within the walls of the vessel, is inversely proportional to the cube of the distance by which the particles are separated. Calling this distance d, this fact is expressed by the equation, $M = \frac{1}{d^3}$ (2); hence equation (1) can be written $P = \frac{n}{d^3}$ (3).

It is now necessary to make some hypothesis as to the nature of the vibration the frequency of which is denoted by n.

I assume that the molecules of any gas are each composed of at least two atoms of equal mass m, and that these atoms are in continuous and, almost inconceivably, rapid revolution around a common center of attraction lying between them, just as are the components of a binary system of stars, and that the law governing the action of this attractive force is the same as that of gravity, *i. e.*, that the force varies inversely as the square of the distance of the atoms from the common center around which they revolve.

The revolution of the stars of a binary system around their common centre of gravity, and also the revolutions of the planets around the sun, are vibrations of this nature, and the number of such vibrations in a unit of time is given by the well-known equation, "Analytical Mechanics," $n = \frac{\sqrt{k}}{a^{\frac{3}{2}}}$ (4), which is one expression for that one of Kepler's laws of planetary motion which asserts that "the squares of the times of revolution of any two planets, around the sun, are proportional to the cubes of the mean distances of said planets from the common center of gravity around which they revolve. In equation (4) which is, as I may say, the *corner stone* of the theory which I have constructed, n represents the mean motion or the angular velocity; *i. e.*, the number of revolutions or complete vibrations in a unit of time; k is the unit of attractive force and is a constant, therefore the only variable is a, which represents the mean distance of the revolving body from

the center of gravity of the system, and, in the case of a circular orbit, is the radius; consequently, considering only relative values, $n = \frac{1}{a^{\frac{3}{2}}}$ (5).

Since I have assumed that the vibrations of the atoms are subject to the same law that governs the revolutions of the planetary masses, it follows that equation (5) will give the value of n used in equation (1), if we replace in equation (5), $a^{\frac{3}{2}}$ by $d^{\frac{3}{2}}$, which can be done because the distance d, between the revolving atoms of each system is equal to $2a$; replacing $a^{\frac{3}{2}}$ by $d^{\frac{3}{2}}$ equation (5) will become $n = \frac{1}{d^{\frac{3}{2}}}$ or $n = \frac{1}{d^{1.5}}$ (6). Substituting this value of n in equation (3) the following results: $P = \frac{1}{d^3} \cdot \frac{1}{d^{1.5}}$ or $P = \frac{1}{d^{4.5}}$ (7); whence $d = \frac{1}{P^{\frac{1}{4.5}}}$ (8).

The last equation expresses the fact that the distance apart of the revolving atoms is inversely proportional to the 4.5th root of the pressure of the gas. The quantity of energy transmitted by the gas, from a given "source of heat," is now to be determined. It is known, from the principles of "Analytical Mechanics," that the quantity of energy, Q, generated by a mass, m, moving with a linear velocity, v, is proportional to the product of one-half the mass into the square of the linear velocity. This fact is expressed by the equation, $Q = \frac{1}{2} mv^2$ (9). If, as before, we denote the mean distance of the revolving mass by a, we find that, since the linear velocity, v, is equal to the angular velocity, n, multiplied by the mean distance a, $v = na$, or as since shown by equation (6), $n = \frac{1}{d^{1.5}}$, $v = \frac{a}{d^{1.5}}$ (10); but as a is proportional to the distance d, being equal to $\frac{1}{2}d$, equation (10) can be written $v = \frac{d}{d^{1.5}} = \frac{1}{d^{\frac{1}{2}}}$ (11); therefore $v^2 = \frac{1}{d}$ (12);

hence $Q = \frac{1}{2}\frac{m}{d}$ (13); but since m is constant we will have $Q = \frac{1}{d}$ (14); and since equation (8) shows that $d = \frac{1}{P^{\frac{1}{4.5}}}$ we can write $Q = P^{\frac{1}{4.5}}$ (15); equation (14) expresses the fact that the quantity of energy transmitted, from a given "source of heat," by and through a gas in any given time, is inversely proportional to the distance apart of the revolving atoms, while equation (15) shows that it is directly proportional to the 4.5th root of the pressure of the gas.

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Equation (15) thus furnishes the theoretical solution of the problem under consideration, but since it is founded upon an assumption as to the nature of the pressure of a gas, which assumption is expressed by equation (1), it is necessary to learn whether the results derived from experiment agree with the deductions from theory. I have found that they do. Experiments have been made by a skillful physicist, upon the radiation of heat from the surface of a mass of copper placed in an enclosing vessel; the difference of temperature between the copper and the walls of the enclosure was 90 degrees Fahrenheit, and the quantity of heat in absolute measure, (*i. e.* in pound-degrees Fahrenheit per second) radiated from each square inch of the surface of the mass of copper was determined, both when the enclosed air was at the ordinary atmospheric pressure of 30 inches of mercury and when the pressure was only 0.4 of an inch, or only $\frac{1}{75}$ of the normal pressure. Taking the normal pressure of 30 inches as the unit, the pressure at 0.4 inches will be represented by the equation $P = \frac{1}{75}$; substituting this value of P in equation (15), the following expression for the relative quantity of heat radiated will be $Q = \sqrt[4.5]{\frac{1}{75}} = .3831+$. The quantity radiated at pressure of 30 inches was .0002271 of a thermal unit; hence, by my theory the quantity radiated at the pressure of 0.4 inches should be .0000870 of a thermal unit; the quantity found by experiment was .0000875 of a thermal unit; certainly a very close agreement between theory and observation.

Another experimental result, even more conclusive, is that furnished by a determination of the quantity of heat radiated from the filament of an incandescent electric lamp. Taking the pressure of the air remaining within the glass-bulb of the lamp at only one-millionth of the ordinary atmospheric pressure, in other words making $P = \frac{1}{1000000}$, I found that the the theoretical result derived by means of equation (15), and expressed in units of electrical energy, was practically identical with those derived from many actual tests upon a 16 candle-power light, these tests having been made by several different lighting companies. This agreement between theory and observation, in cases where the relative pressures, viz.: $\frac{1}{75}$ and $\frac{1}{1000000}$, differed so widely seems to me to establish the truth of the hypothesis upon which the theoretical results above given are based, and the validity of the law expressed by equation (15).

By another, but indirect, method the legitimacy of the assumption expressed by equation (1) and of the results flowing therefrom, in regard to the *orbital* motion of the atoms under the in-

fluence of a centripetal force which varies inversely as the square of the distance, can also be established. Boyle's law asserts that the pressure of a gas when the temperature of the latter remains constant, is proportional to the density of the gaseous mass; this law is expressed by the equation $P = D = \frac{M}{V}$ (16), in which P represents the pressure, D the density, M the mass, and V the volume of the gas. If the density be varied either by an addition to, or an abstraction from the mass, the volume remaining constant, we will have $P = M$ (17). If the variation of density be effected by changing the volume, the mass remaining constant, the pressure will be given by the equation $P = \frac{1}{V}$ (18); therefore both mass and volume being variable, the pressure will be directly proportional to the mass, and inversely proportional to the volume; hence the ratio between any two pressures, P_1 and P_2, should, if Boyle's law be perfectly true, be expressed by the equation $\frac{P_1}{P_2} = \frac{V_2}{V_1} = \frac{M_1}{M_2}$ (19); but, as a matter of fact, the ratio of the pressures does not follow, exactly the law expressed by the equations (19), but is represented by the following:

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{1.41} = \left(\frac{M_1}{M_2}\right)^{1.41} (20),$$

in which the exponent 1.41 represents the ratio between specific heat at constant pressure and specific heat at constant volume. This ratio has never been determined, so far as I know, otherwise than by experimental research. I will now endeavor to demonstrate that it can be derived analytically, and also to show its signification, *i. e.*, that it is due to the *orbital* motion of the revolving atoms, and is a function of the factor, n, in equation (1).

Comparing equation (17), or $P = M$, with equation (1) or $P = Mn$ we see that they differ by only the factor n, which represents the angular velocity or the number of vibrations of the atoms, around their common center of attraction in unit time; therefore I claim that the exponent 1.41 in equation (20), or the ratio between specific heat at constant pressure and that at constant volume, depends upon n, or the angular velocity of the revolving atoms. According to equation (7), $P = \frac{1}{d^{4.5}}$; but, since the volume V is proportional to the cube of the distance between the atoms, $d^3 = V$, and therefore $d^{4.5} = V^{1.5}$; hence equation (7) can be written: $P = \frac{1}{V^{1.5}}$ (21). Furthermore, since the mass M

is inversely proportional to the cube of the distance, $M = \frac{1}{d^3}$ and $\frac{1}{d^{4.5}} = M^{1.5}$, but from equation (7) $\frac{1}{d^{4.5}} = P$, therefore $P = M^{1.5}$ (22). If we now consider the ratio between any two pressures, P_1 and P_2, we find that $\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{1.5} = \left(\frac{M_1}{M_2}\right)^{1.5}$ (23).

Comparing these expressions with equations (20) we cannot fail to note a resemblance so strong as to force us to the conclusion that they are identical, and we may, I think, regard the exponent 1.5 which, as we have seen, results from the assumption of an orbital motion of the atoms whose angular velocity is denoted by the factor n, in equation (1), as representing the ratio between specific heat at constant pressure and specific heat at constant volume. It is true that it differs slightly from 1.41, the value generally accepted, but this value has been determined from experiments on the velocity of sound in air, which experiments are, of course, subject to more or less error, and since the effect of moisture in the atmosphere is not well known, the slight discrepancy may be regarded as of no importance, and the value of the ratio between the specific heats, in the case of perfect gases, can, I think, be taken as 1.5.

The nature of this quantity can be better understood if illustrated by an example. If we reduce the volume of a gas by any amount, one-half for instance, the pressure would be, by Boyle's law expressed by equation (20), inversely proportional to the amount of the reduction; *i. e.*, in this case it would be doubled, but, as a matter of fact, when no heat is allowed to enter or to escape from the gas, the pressure is found to be more than double being in this case, according to equation (23), equal to $2^{1.5}$ or to 2.83, the difference between 2 and 2.83 representing the increase of the orbital velocity, due to the decrease of the distance, d, between the atoms of each molecule of the gas, which decrease is caused by the compression of the latter, and this increase of vibrational velocity represents the quantity of heat generated in the gas by the compression. If a gas confined in a vessel be heated from an external "source of heat," it tends to expand, but since the volume remains constant the gas cannot expand and its tendency to do so causes an increase of pressure, consequently by reason of this increase it is still further heated, and a less quantity of applied or external heat is required to raise the temperature of the gas through one degree, than would be required if the gaseous mass were free to expand so that the distance d, between

the atoms could become greater and therefore the orbital motion, or the *internal heat* be decreased.

The ratio between the quantities of external heat necessary to be applied in order to raise the temperature of the gas through one degree in the respective cases where the gas is kept at constant pressure and at constant volume, is the quantity whose commonly accepted value is 1.41 but which is, as I have shown, properly 1.5.

[TO BE CONTINUED.]

BRORSEN'S SHORT PERIOD COMET.*

GEORGE A. HILL.

FOR GENERAL ASTRONOMY.

The return of Brorsen's comet, which, according to the advance calculations of Professor E. Lamp, had confidently been expected to occur in the beginning of the past year, has not taken place. It will, therefore, be not uninteresting, to look back, in this article, at the condition of brightness and visibility under which this comet has been observed up to the present time; for in this manner we are best enabled to perceive in how far we were justified to expect with certainty its reappearance during the opposition of last year.

The circumstance that the period of the comet is nearly 5.5 years—the great perturbations of Jupiter in September 1866, decreased it from 5.54 to 5.48 years—causes the returns to perihelion to divide themselves into spring and autnmn appearances. The former are extraordinarily favorable for observation, since, at that time the comet, in consequence of its great inclination, reaches a high northerly declination; in the latter, the comet remains always near the equator, and is visible, if at all, only in the morning hours shortly before sunrise.

We will first consider the spring oppositions which have been observed, up to the present time, 1846 III, 1857 II, 1868 I and 1879 I. In the opposition of 1857, the comet was discovered independent of the ephemeris; its identity with 1846 III was established only through the calculation of its orbit. Van Galen had furnished an advance calculation for this return, but which in consequence of erroneous computation fixed the date of perihelion passage a fourth of a year too late, and would, therefore, not have led to the discovery of the comet.

* Translated from the Vierteljahrsschrift der Astronomischen Gesellschaft, 26 Jahrgang Erstes Hept.

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In the last two named appearances, the comet was found according to ephemerides computed by Plummer and Schulze.

The following ephemerides will furnish a review of the apparitions in question. "H" expresses the factor of brightness $\frac{1}{r^2 \Delta^2}$; the first place of the ephemeris is the date of discovery, the last is the date of the last observation.

1846 III.
Perihelion Feb. 25.

1846		α h	δ °	H
Feb.	26	1	+14	5.4
March	10	1	34	6.4
	21	0	52	5.5
April	1	23	67	4.4
	22	17	+71	2.1

1857 II.
Perihelion March 29.

1857		α h	δ °	H
March	18	2	+ 8	1.7
April	6	3	30	2.8
	18	4	45	2.9
May	2	6	60	2.3
	12	9	63	1.7
Jan.	1	12	48	0.8
	22	13	+30	0.3

1868 I.
Perihelion April 17.

1868		α h	δ °	H
March	22	2	0	0.6
April	11	3	+17	1.5
	18	4	24	1.9
	27	4	33	2.1
May	12	6	46	1.9
June	1	10	49	1.2
	23	12	+34	0.5

1879 I.
Perihelion March 30.

1879		α h	δ °	H
Jan.	14	23	−29	0.1
Feb.	19	1	14	0.5
Mar.	1	1	− 7	0.7
	20	2	+ 9	1.9
April	10	3	23	3.3
May	1	6	60	2.9
	12	8	65	2.2
	23	11	+58	1.3

In connection with the foregoing review the following details should receive attention:

1846 III. The last observations were made in Bonn, April 21, and in Berlin, April 22. The Washington observations of the latter part of May (referred to by Bruhns, A. N. 1686, Carl Repertorium, Annuaire du bureau des longitudes) are based upon a confounding of this comet with another, 1846 VII, also discovered by Brorsen.

1857 II. In general, the observations cease with the end of May. From June 18 to 22 the comet, greatly reduced in brightness, was observed only at Berlin.

1868 I. The first re-discovery by Tempel, on March 22, seems doubtful; the comet was not seen with certainty until April 11. In June, the comet was seen only by Schmidt at Athens.

1879 I. The regular ephemeris begins in the middle of March; prior to that time, the comet was seen only Jan. 14 in Arcetri, Feb. 17, in Rome, and Feb. 26, at Windsor.

Noteworthy is the small light intensity of the comet when discovered by Tempel on Jan. 13, in a very southerly declination.

With regard to the brightness of the comet, we may accept it as an established fact that, notwithstanding the smaller theoretical light intensity, the comet was considerably brighter in 1857 than in 1846. Schmidt at Olmütz even believes that he saw the comet with the naked eye on April 8-12, 1857—a brightness which it has never before or since reached. In the year 1868, the comet was fainter than in 1857, but this may be explained by the less favorable conditions of light. In the opposition of 1879, the comet occupied the same position in the heavens as in 1857, but, as may be concluded from the early discontinuance of the observations—it does not appear to have reached the same degree of brightness as formerly.

The general appearance of the comet in the three apparitions 1857, 1868 and 1879, remained always the same; it was that of a large, pale nebula of 4′ diameter, with a condensation in the centre that was very distinct at the time of perihelion, but, which, according to the concurrent testimony of all observer did not condense itself into a star-like neucleus.

In the year 1846, this strong exhibit of light in the centre of the comet did not take place, a circumstance which will most readily explain the relative faintness of light connected with that apparition.

A characteristic phenomenon connected with Brorsen's comet, and one observed at all returns, is the rapid decrease of light which takes place several weeks after its perihelion passage, and which appears to be connected with a considerable increase of its diameter, amounting to 8′ to 10′.

In the year 1846, when this phenomenon was observed for the first time, the comet, as described by D'Arrest in A. N. 1079, appeared to dissolve in such a manner in its departure from the sun, "that for this reason its reappearance was considered very doubtful at the Berlin Observatory." The fact that in all returns, so soon as the brightness had fallen below unity, observations were possible only in exceptional cases, is directly connected with this phenomenon.

Before the perihelion passage the faintness of light does not appear to be so pronounced as afterwards; at least we could not otherwise explain the fact that in the year 1879, Tempel was able to find the comet on Jan. 14, and Tebbutt could observe it on Feb. 26 with a 4½-inch refractor.

Of the unfavorable autumn returns, the only one observed thus far, is the apparition 1873 VI, perihelion Oct. 10. In this apparition, the comet was discovered Aug. 31, according to ephemeri-

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des by Plummer and Schulze, and observed until Oct. 26. It was always faint, of a diffused appearance and without noticeable condensation. The maximum theoretical brightness, 20, was attained in the beginning of October, a brightness which caused the comet, in 1868, to appear as an object of the eighth or ninth magnitude; but in the latter case, the increased faintness of light is fully explained by the comet's unfavorable position in the morning sky.

In the years 1851, perihelion Sept. 22, and 1884, perihelion Sept. 14, the comet was nearer the sun than in 1873, so that under those conditions, its non-discovery is fully accounted for. In view of the comet's non-appearance during the past year, it would, at all events, be of great interest to learn whether and to what extent, especially in the year 1884, search was made for it. Up to the present time, only two short notices have appeared on this subject, one by Trépied (A. N. 2614), and the other by Pechüle (A. N. 2710). In the year 1862, the perihelion passage occured about Oct. 12; it would, therefore, have been possible to have discovered the comet, as is shown by the apparition of 1873—if an ephemeris had been available.

According to the advance computation of Professor E. Lamp, the perihelion passage in the year 1890 occurred on Feb. 24; the return should, therefore, have been exactly analogous to the very favorable first return, 1846 III.

As, notwithstanding this fact the comet was not found either before or after its perihelion passage, we are necessarily compelled, from what has been said above, to conclude that its lack of brilliancy was such as to be out of all proportion with that of former returns.

Whether the comet has actually been lost to us will have to be decided by subsequent observations.

A complete discussion of the hitherto observed returns of Brorsen's comet is yet to come. Professor Lamp is at present en gaged in adjusting the last three appearances 1868 I, 1873 VI and 1879 I. Although his investigations are not yet concluded, he feels himself already justified in saying that a combination of the three returns is not possible without an empirical change in the mean daily motion. *Written by* H. KREUTZ.

The above article which I have translated from the magazine published by the German Astronomical Society will be found to contain many interesting facts connected with the history of one of the short period comets that seems to have gone astray.

In connection with what Mr. Kreutz has said, I desire to add that I searched for this comet on 22 nights between Dec. 16, 1889, and March 11, 1890.

I first started with an ephemeris I had computed by the aid of the elements determined in 1879 by Professor Schulze.

It will be remembered that his elements placed the comet in the evening sky, to the east of the sun. Mr. Wittstine had determined a set of elements from observations made in 1879, and there is quite a difference between the value of the mean daily motion of the Schulze and the Wittstine elements, so much so that the latter elements gave an ephemeris that placed the comet on the west side of the sun, nearly 40° from the place indicated by the Schulze elements. This led me to take the observations made of the comet in 1879 and compare them with Professor Schulze's orbit which had been computed from the observations of 1868 and 1873 and the perturbations allowed for in the interval.

For a short time before perihelion, in 1879, the ephemeris agrees fairly well with observations, but after perihelion, say, from April 10th to the last observation made, May 23, the difference between computed and observed places is very large indeed.

I do not feel competent to criticise Professor Schulze's work upon the orbit of this comet, but I am positive that some errors have inserted themselves into his calculation.

The orbit I have determined from the observations extending from March 10 to May 23, 1879, differs quite a good deal from his, not only in the mean daily motion, which I find to be smaller, but in the longitude of the perihelion and the node.

I hope to be prepared to publish before the next return of the comet, my discussion of the several returns and the elements corrected for the perturbations between 1879 and the next apparition.

Naval Observatoy, Washington, D. C.

THE SPECTRA OF STARS WITH LARGE PROPER MOTION.

J. E. GORE, F. R. A. S.

For General Astronomy.

In his note on Star Distribution in the November number of The Messenger, Mr. Monck suggests that "solar stars of any magnitude will, on the average, have a greater proper motion

than the Sirian." To test the accuracy of this prediction I have gone through the Draper Catalogue of Stellar Spectra, a valuable volume recently issued from the Harvard Observatory, and the results are given in the following table. The magnitudes and proper motions of the stars are taken from Miss Clerke's valuable work, "The System of the Stars." Some of the fast moving stars are either too faint or too far south to be included in the Draper Catalogue. It will be seen that of 29 stars of which the spectrum has been determined, 26 stars are of the second or solar type, a striking confirmation of the truth of Mr. Monck's theory.

Star.	R. A. 1900.		Dec. 1900.		Mag.	Annual Proper Motion.	Spectrum.
	h	m	°	′		″	
Groombridge 1830,.....	11	46.9	+ 38	31	6.5	7.0	I (A?)
61 Cygni, Double.....	21	2.1	+ 38	13	5.1	5.2	II (H)
40 Eridani, Triple.....	4	10.7	− 7	47	4.4	4.1	II (H?)
μ Cassiopeiæ.....	0	1.2	+ 54	27	5.2	3.7	II (H)
P II 123.....	2	30.5	+ 6	24	6.3	2.4	II (H)
α Bootis.....	14	11.1	+ 19	44	0.2	2.3	II (K)
Bradley 3077.....	23	8.3	+ 56	36	5.9	2.1	II (H)
τ Ceti.....	1	39.5	− 16	28	3.6	1.9	II (G?)
σ Draconis.....	19	32.5	+ 69	31	4.7	1.9	II (I?)
61 Virginis.....	13	13.2	− 17	45	4.8	1.5	II (H)
B.A.C. 160 (?).....	0	32.1	− 25	19	5.6	1.4	II (F)
20 Mayer.....	0	43.1	+ 4	46	5.7	1.4	II (H?)
Groombridge 1618.....	10	4.0	+ 50	0	6.5	1.4	II (H)
ι Persei	3	1.8	+ 49	14	4.1	1.3	II (F)
Weisse IV, 1189.....	4	57.1	− 5	39	6.5	1.3	I (A)
Sirius, Double; binary.....	6	40.7	− 16	34	−1.4	1.3	I (A?)
Procyon.....	7	34.1	+ 5	30	0.5	1.3	II (F)
Lalande 27744.....	15	8.9	− 0	58	7.0	1.3	II (H)
γ Serpentis.....	15	51.8	+ 16	0	4.0	1.3	II (F)
85 Pegasi, Double; binary.....	23	56.8	+ 26	34	5.8	1.3	II (E)
η Cassiopeiæ, Double; binary..	0	43.0	+ 57	17	3.6	1.2	II (F)
δ Trianguli.....	2	10.8	+ 33	46	5.0	1.2	II (F)
43 Comæ.....	13	7.3	+ 28	22	4.4	1.2	II (F)
36 Ophiuchi, Double.....	17	9.2	− 26	27	4.7	1.2	II (I)
θ Ursæ Majoris.....	9	26.3	+ 52	8	3.2	1.1	II (F)
70 Ophiuchi, Double; binary....	18	0.4	+ 2	32	4.1	1.1	II (K)
Lalande 16304.....	8	13.7	− 12	18	6.0	1.0	II (E)
w (72) Herculis.....	17	16.9	+ 32	37	5.4	1.0	II (E)
b (31) Aquilæ.....	19	20.2	+ 11	43	5.3	1.0	II (H)

To the above may be added α Centauri which has a proper motion of 3″.7 per annum, and I believe a spectrum of the solar type.

CAPTURE OF COMETS BY PLANETS.

H. A. NEWTON.

In a paper published in 1878 I obtained a simple expression for the change of energy of a small body, a comet for example, that passes near enough to a large planet to have its orbit so ser-

iously changed that all the minor terms in the perturbation may be disregarded. The great interest recently shown in this particular problem of perturbation has led me to take up again the formula, and deduce some results that logically follow from it. The details of the algebraic work are given in a paper in the *American Journal of Science* [3] vol. XLII, Sept. and Dec., 1891. Some of the principal results are given below. Most of the computations made refer to the case of comets moving originally in parabolic orbits about the sun, and passing very near to the planet *Jupiter*, though small changes will make the reasonings apply equally to other comets and planets.

1. The different ways in which such comets can approach *Jupiter* may, by disregarding the plane of *Jupiter's* orbit about the sun, be treated as depending on three independent variables. Let d be the shortest distance between the orbit of the planet and the unperturbed orbit of a comet, ω the angle between the two tangents to those orbits at the extremities of d, and h the distance *Jupiter* has yet to travel to reach one end of d at the moment when the comet would if unperturbed be at the other end of d. The elements of a given cometic orbit, along with the elements of *Jupiter's* orbit, furnish easily the corresponding values of d, ω and h.

2. The loss of energy during the whole transit of the comet past the planet is capable of expression in terms of d, h and ω. Hence the semi-axis major of the elliptic orbit after large perturbation may be expressed in terms of the same three quantities. In other words, the elements of the orbits of the comet and the planet before perturbation furnish the means of computing directly and simply the periodic time of the comet after a large perturbation.

3. If m is the mass of the planet, r its distance from the sun, and if s, A and ϑ are functions of ω defined by the equations

$$s^2 = 3 - 2\sqrt{2}\cos\omega,\ A = \frac{mr}{s^2} \text{ and } 2s\cos\vartheta = 1 - s^2,$$

then the equation

$$a = \frac{s}{4m} \cdot \frac{A^2 + d^2 + h^2\sin^2\vartheta}{A\cos\vartheta + h\sin^2\vartheta}$$

gives a the semi-axis major of the elliptic orbit of the comet about the sun after perturbation; if a is negative it is the half of the transverse axis of the resulting hyperbolic orbit.

4. For a given value ω and a given positive value of a the two quantities d and h can be treated as the abscissa and ordinate of an ellipse. For values of d and h corresponding to points

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within the ellipse a is smaller than for values of d and h corresponding to points upon or outside of the ellipse. As a varies the ellipses constitute a *faisceau* of similar and similarly situated ellipses having the straight line $A\cos\vartheta + h\sin^2\vartheta = 0$ for their common radical axis. For points above the radical axis the final orbit is an ellipse, for points below it is an hyperbola.

5. The greatest effect of pertubation of a planet moving in a circular orbit in shortening the periodic time of a comet moving originally in a parabola is obtained if the comet's original orbit actually intersects the planet's orbit at an angle of 45°, and if the comet is due first at the point of intersection at the instant when the planet's distance therefrom is equal to the planet's distance from the sun multiplied by the ratio of the mass of the planet to the mass of the sun. The relative velocity of the comet on leaving the planet's sphere of action, would be equal to and directly opposite to the planet's velocity, and the comet would be left entirely at rest to fall to the sun.

6. In order to facilitate the consideration of the effect of a planet upon comets as a group two arbitrary assumptions have been made relative to the distribution of the comets themselves, and the distribution of the directions of their motions.

(*a*) If about the sun as a center a spherical surface S be described with an arbitrary radius, it is assumed that near S space is filled equably with comets.

(*b*) It is further assumed that the directions of the comets in each cubic unit of space near S are at random: that is, that the quits and goals of the comets' motions relative to the sun are distributed equably over the surfac of the celestial sphere.

So far as these assumptions are not true in nature, so far modifications of conclusions resting upon them will need to be made.

7. It follows from the assumptions of (6) that if comets be grouped according to their perihelion distances the number of comets whose perihelion distances are less than q is proportional to q.

8. If the two assumptions are true for a spherical surface S, they will be true for every smaller concentric surface.

9. It also follows that if r is the planet's distance from the sun, and r' is small relative to r, the number of comets, which, in a given period of time come nearer to the sun than r is to the number that (unperturbed) come nearer to the planet than r' as $6r^3$ is to $7r'^2$. The factor $\frac{7}{6}$ expresses the increase of numbers caused by the planet's motion in its circular orbit.

10. The number of comets which in a given period of time pass their perihelia nearer to the sun than a given planet, is to the number of comets whose periodic times are reduced by the perturbing action of the planet so as to be less severally than one-half, once, three-halves, and twice, the periodic time of the planet, as unity is to the square of the mass of the planet multiplied severally by 0.139, 0.925, 1.876 and 2.943.

11. With the same assumptions, and regarding the planet as without dimension so as to intercept any comets, if in a given period of time a thousand million comets come in parabolic orbits nearer to the sun than *Jupiter*, 126 of them will have their orbits changed into ellipses with periodic times less than one-half that of *Jupiter;* 839 of them will have their orbits changed into ellipses with periodic times less than that of *Jupiter;* 1701 of them will have their orbits changed into ellipses with periodic times less than once and a half-times that of *Jupiter;* and 2670 of them will have their orbits changed into ellipses with periodic times less than twice that of *Jupiter.*

12. Of the 839 comets whose periodic times after perturbation are less than *Jupiter's* period, 203 will after perturbation have retrograde motions, and 636 will have direct motions. Also 267 of them will have quits less than 45° from *Jupiter's* quit, while 38 of them will have quits less than 45° from *Jupiter's* goal. Also 257 of them will move in orbits whose planes are inclined less than 30° to *Jupiter's* orbit, while 51 will move in orbits inclined more than 150° to *Jupiter's* orbit.

13. Each comet has been thus far considered as approaching *Jupiter* while moving in a parabolic orbit about the sun. If the comet, however, is moving in any other orbit, and it passes near to the planet, the result of the planet's perturbing action will in general be quite similar to the result when the orbit is parabolic, the other circumstances of the approach being assumed to be alike in the two cases.

The above conclusions refer moreover to perturbations during one transit of the comet past the planet. But the comet, unless the orbit is still further changed by another planet, must return at each revolution to the place where it encountered *Jupiter.* At some time *Jupiter* will be nigh that place nearly at the same time as the comet, and the comet will suffer a new, and perhaps a large perturbation. Its period will again be changed, being shortened or lengthened according as the comet passes before or behind the planet. The process will be repeated again and again, since after any number of encounters the new orbit of the comet will still pass near to the orbit of the planet.

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This repeated action makes it possible, and even usual, to have an orbit shortened in period by several passages near to *Jupiter* instead of its being done at one passage. A much larger proportion of comets than 839 out of 1,000,000,000 must therefore have their periodic times reduced below the period of *Jupiter.*

If the comet's orbit is largely inclined to the ecliptic, and hence its motion makes a large angle with that of *Jupiter*, there is nearly an even chance that the velocity will be increased or diminished. A considerable fractional part of the whole number of such comets will at each passage be thrown out of the solar system altogether, or thrown into such long orbits that they will return only at very great intervals of time. This class of comets cannot be therefore regarded as permanent members of the family of short period comets, except such of them as happen to come so near to other planets as to have their orbits changed in such wise that they do not have thereafter the near approach to *Jupiter's* orbit. But when an orbit is greatly inclined to the plane of the solar system the comet passes through the plane in general at a considerable angle, and the chance of coming close to another planet is relatively small.

On the other hand, all the comets which after perturbation are moving in orbits somewhat, but not greatly inclined to the ecliptic, are liable to meet, (in fact, are sooner or later almost certain to meet) other planets in such a way as to suffer perturbations that will prevent future close encounters with *Jupiter.* After such changes those comets must be regarded as tolerably permanent members of the solar system.

Comets that have motions not greatly inclined to *Jupiter's* motion are more likely in subsequent passages near to *Jupiter* to have their periodic times shortened than lengthened. On the contrary, those passing in nearly opposite direction to *Jupiter's* motion will be quite sure to have their periods lengthened rather than shortened.

All these causes combine and work together to the one end that those comets which are changed by the perturbing action of *Jupiter*, or other planets, from parabolic orbits of every possible inclination to the ecliptic into short period ellipses, and become permanent members of the solar system, will as a rule (but with exceptions) move in orbits of moderate inclination to the ecliptic, and with direct motions.

We know as a fact, that most short period comets do move in orbits having small inclinations and direct motions, while long period and parabolic comets move at all possible inclinations to the ecliptic. If the short period comets have been changed by *Jupiter* and other planets from parabolic orbits, the preceding investigation shows why their orbits have now small inclinations to the ecliptic, and the comets themselves have direct motions.

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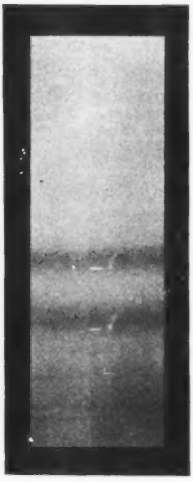
PLATE III.

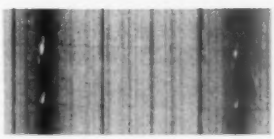


Eruption photographed July 9, 1891, at Chicago, 11h. 55m. A.M. Chicago M.T.
(7h. 1m. P.M. Kalocsa M.T.)

Eruption drawn July 9, 1891, at Kalocsa, Hungary,
at 7h. 0m. P.M. Kalocsa M.T.

PLATE IV.

Prominence photographed Oct. 20, 1891, at 2 h. 30 m. P. M.



Distortion of Calcium lines photographed Oct. 20, at 10 h. 58 m. A. M. Showing velocity of 64 miles per second toward the earth.

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ASTRO-PHYSICS.

THE ASTRO-PHYSICAL JOURNAL.

It was early in June of the present year that the publication of a journal devoted to spectroscopy and astro-physics was suggested to the writer by Professor C. A. Young, but a projected European trip allowed no definite action to be taken at that time. While abroad, however, an opportunity was afforded of discussing the matter with many astronomers and spectroscopists, and the interest so generally manifested led to the belief that strong support and a wide field of usefulness might be expected for such a publication. It is very evident to anyone acquainted with the present condition of astronomy and physics that in these sciences no one instrument plays a more prominent part than the spectroscope. Long recognised as a powerful means for the chemical analysis of near and distant luminous bodies, it has but recently been promoted to the distinction of an instrument of precise astronomy, in consequence of its closely concordant measures of stellar and nebular motion in the line of sight. This upward step, long since foreseen by our still active pioneer, Dr. Huggins, has disarmed whatever of prejudice against the spectroscope that may have existed among members of the older school of astronomy, and few observatories are considered fully equipped without this efficient aid to research. With its recent rapid developments spectroscopy may well be regarded as having entered upon a new and promising era of progress; already we are in reach of a simple and direct method of determining the distance of the sun by its means, and the relations now known to exist between the spectra of some of the elements suggest equally important advances to the physicist.

On account of its manifest importance, and its appeal to astronomers, physicists, and, to some extent, chemists, it is much to be regretted that the literature of spectroscopy is so widely scattered. Few investigators are so fortunate as to have easy access to the files of all the journals, the innumerable publications of learned societies, and the annals of all observatories. Again, however perfect may be the familiarity of the English-speaking scientist with languages other than his own, there can be no doubt that he allows to pass unread many papers which would at least be rapidly scanned for points of importance, were they printed in English.

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For these and other reasons the publication of an astro-physical journal seemed eminently desirable. The question has been thoroughly discussed in conversation with Professor Young, Dr. Huggins, Professor Vogel, Dr. Scheiner, Mr. Ranyard, Herr Schumann, Professors Liveing and Dewar, M. Deslandres, M. Trouvelot, Professor Pickering, Professor Hastings, Professor Keeler and many others. All expressed interest in the idea, and promised to assist the journal by the contribution of papers. But there were many objections to adding another to the already long list of astronomical publications, and Professor Payne's recent suggestion of a union with THE SIDEREAL MESSENGER was considered so desirable that it was at once accepted. Though printed with THE MESSENGER, which will be seen to have undergone many modifications and improvements, THE ASTRO-PHYSICAL JOURNAL will have an individuality of its own, and fully as much space will be devoted to it as would be the case in a separate publication.

It shall be our endeavor to bring our papers both to the astronomer and to the physicist, for in many cases the spectroscopist can ill afford to lose either portion of his audience. Translations and reprints of important papers will be freely used, the idea being to place within reach of all a large portion of the current literature of astro-physics.

We append below a number of letters which have been received with permission to publish. Supplementing as they do the promises of support already mentioned, there seems to be sufficient reason to confidently hope for success. It should be added that most of the letters were written before a union with THE SIDEREAL MESSENGER had been suggested. All who have since heard of this plan heartily approve of it.

UPPER TULSE HILL, London, S. W., 28 Oct., 1891.

Professor George E. Hale,

DEAR SIR:—I am very pleased indeed to hear that you intend to carry out the project you mentioned to me when you were in England, of publishing an Astro-Physical Journal.

I think that you have a very large and unworked field before you, and I wish you most heartily the highest success possible. It will be a pleasure to us to send you any papers we may have, at as early a date as possible, for insertion in your new journal. . . . . .

Yours sincerely,
WILLIAM HUGGINS.

THE OBSERVATORY, PRINCETON, N. J., Oct. 17, 1891.

My Dear Mr. Hale:—

. . . . . .

As to the Journal, I am delighted to hear that you have finally decided to undertake its publication. I think it will be extremely useful and valuable, and I most cheerfully promise to do whatever I can to aid you in the enterprise.

. . . . . .

Yours sincerely,
C. A. YOUNG.

OBSERVATOIRE D'ASTRONOMIE PHYSIQUE DE PARIS,
Meudon, le 21 Nov., 1891.

Cher Monsieur:

J'ai beaucoup regretté de ne pas m'être trouvé à Meudon quand vous y avez passé. J'aurais aimé à causer avez vous de l'intéressant observatoire consacré principalement à la spectroscopie, que vous fondez vous-même, et où vous avez déjà obtenu de remarquables résultats.

Vous m'écrivez que vous voulez fonder un journal spécialement consacré à la spectroscopie et vous me demandez mon avis.

Je pense que tous les astronomes physiciens ne pourront que vous encourager et vous aider. Un recueil, même non regulièrement périodique, qui nous donnerait les travaux et les découvertes en spectroscopie, résumés autant que possible par les auteurs eux-mêmes, aurait un bien grand intèrêt et plus tard serait bien précieux pour l'histoire de cette spectroscopie céleste dont l'avenir est immense.

En vous souhaitant plein succès je vous prie de croire à mes sentiments les plus distingués et dêvoués. J. JANSSEN.

CAMBRIDGE, England, 1 Nov., 1891.

To Professor George E. Hale,

DEAR SIR:—It is with pleasure that we have learnt your intention to publish an Astro-Physical Journal. The great advances in our knowledge of the physics of the heavenly bodies consequent on the use of the spectroscope, and the increasing number of workers in that line of research, seem to us good reasons for thinking that your proposal will meet a want of the time. Moreover it seems to us very fitting that the Journal should be published in America, where there are not only many excellent observers possessing first-class instruments, but also a climate far better suited for astronomical observations than we on this side the Atlantic enjoy. We shall be glad to coöperate in the undertaking so far as it lies within our power. We are, dear sir, very truly yours,

G. D. LIVEING,
JAMES DEWAR.

HARVARD COLLEGE OBSERVATORY, Cambridge, Oct. 19, 1891.

Professor G. E. Hale, Kenwood Physical Observatory, Chicago,

DEAR SIR:—The plan which you have formed for the publication of THE ASTRO-PHYSICAL JOURNAL appears to me very judicious, and I think that the work will be of much value and interest. Your intention of making it include translations of articles from foreign journals fully commends itself to me. It will give me pleasure to communicate to THE ASTRO-PHYSICAL JOURNAL any observations made here which relate to the problems to be discussed in it, and such remarks upon those problems as I can find time to prepare.

Very truly yours,
EDWARD C. PICKERING.

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915 CATHEDRAL STREET, BALTIMORE, Dec. 4, 1891.

DEAR SIR:—The science of spectroscopy has certainly advanced far enough to furnish material for a new journal, and I have no doubt that the publication of your ASTRO-PHYSICAL JOURNAL would do much to still further advance the subject. I shall do all I can to make it a success, and hope that others will do likewise.

Yours sincerely,
HENRY A. ROWLAND.

PARIS, le 5 Nov., 1891.

Monsieur:—

Au retour d'un assez long voyage je trouve votre lettre et m'empresse de vous remercier de vos aimables propositions.

Je serai très heureux et très honoré de recevoir l'hospitalité dans THE ASTRO-PHYSICAL JOURNAL; je regrette seulement de n'avoir pas présentement à vous adresser un memoire digne de figurer à côté de ceux des savants illustres qui sont déjà vos collaborateurs.

Je serai particulièrement disposé à vous envoyer quelques résultats relatif à la spectroscopie pour les faire connaitre au public Américain; je me souviens trop

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bien tout ce que je dois à vos savants compatriotes L. Rutherford et le Professor Rowland, dont les admirables réseaux m'ont été si utiles dans mes recherches.

Veuillez agréer, je vous prie, Monsieur, l'expression de mes sentiments bien dévoués. A. CORNU.

SMITHSONIAN INSTITUTION, Washington, D. C., Oct. 21, 1891.

DEAR SIR:—I have the honor to acknowledge the receipt of your letter of the 15th instant, advising me that you contemplate publishing an ASTRO-PHYSICAL JOURNAL about the first of December. I can heartily assure you of my interest and good wishes for the undertaking, and I shall hope to have an opportunity of communicating results of observations made in the Smithsonian Astro-Physical Observatory in due time.

. . . . . .

Yours very truly,
S. P. LANGLEY, Secretary.

WILLESLIE HOUSE, 1, Wetherby Place, London, S. W., 22 Nov., 1891,

DEAR SIR:—Owing to an absence I was unable to reply to your letter before. I shall be glad to send you advance sheets of my papers to the Royal Society. I am sure that a journal, such as you propose bringing out, will be most useful to astronomers and physicists, and should command support on both sides of the water. The bill of fare which you promise in your first number will be sufficient evidence of the useful scope of the JOURNAL.

Wishing you all success in your enterprise, Believe me, yours faithfully,
W. DE W. ABNEY.

ALLEGHENY OBSERVATORY, Allegheny, Penna., Oct. 15, 1891.

Professor George E. Hale, Chicago, Ills.,

MY DEAR SIR:—I am glad to learn from your letter of Oct. 12, that you intend to start a journal devoted to astro-physics and spectroscopy. There seems to be a good field for such a journal in this country, and I have no doubt that the enterprise will have the success it merits.

It will give me pleasure to send you occasional contributions from this observatory.

Yours very truly,
JAMES E. KEELER.

ROYAL OBSERVATORY, Greenwich, London, S. E., Oct. 27, 1891.

DEAR SIR:—I am very glad to learn of your intended enterprise, and most heartily wish you all success in it. I feel sure it will do much good by increasing the interest felt in Physical Astronomy, and possibly by bringing forward new workers. If I am able in any way or at any time, to help, I shall be very pleased to do so, though I fear that any assistance I may be able to render will be of the slightest.

Yours very truly,
E. W. MAUNDER.

LEIPZIG, den 4 Nov., 1891, No. 25 Mittelstrasse.

HOCHGEEHRTER HERR!—Ihre Absicht, demnächst ein spectroskopisches JOURNAL herauszugeben, begrüsse ich mit Freuden, denn eine Zeitschrift, die speciell der Spectroskopie gewidmet ist, existirt zur Zeit nirgends. Was die Spectralwissenschaft zu Tage fordert, gelangt meist in Journalen verschiedenen Inhalts zur Publication; hierdurch wird die Orientirung auf spectralen Gebiete ungemein erschwert. Der Spectroskopiker setzt sich demzufolge mehr wie jeder andere Forscher der Gefahr aus, wiederzuentdecken, was schon andere vor ihm ausfindig gemacht haben. Das wird besser werden, sobald die Spectroskopie über eigene Organe verfügt. Ihr Unternehmen, die Gründung einer solchen Zeitschrift, dürfte sonach einen längst gehegten Wunsche aller Spectralkundigen entsprechen. Ich wünsche Ihnen besten Erfolg dazu.

Meine spectralen Ergebnisse, die Ihnen zum Theil aus eigener Anschauung bekannt sind, werde ich Ihnen nach und nach zur Aufnahme in Ihr spectroskopisches JOURNAL zukommen lassen. Die Spectrogramme kleinster Wellenlänge

($<\lambda 1800$), die dem Spectrum des Wasserstoffs angehören, werde ich Ihnen ebenfalls zur Verfugung stellen, sobald meine photographischen Aufnahmen im evacuirten Raume zum Abschluss gelangt sind.

Mit vorzüglicher Hochachtung,

V. SCHUMANN.

LICK OBSERVATORY, Mt. Hamilton, Nov. 10, 1891.

My Dear Mr. Hale:—

I sincerely congratulate you on having found a satisfactory means of publishing THE ASTRO-PHYSICAL JOURNAL, and I wish you every success in your plan. I have no doubt whatever that you will command success, and it will be our pleasure to give you all the support which we can from Mt. Hamilton.

With kind regards, sincerely yours,

EDWARD S. HOLDEN.

STONYHURST OBSERVATORY, Lancashire, Nov. 2, 1891.

George E. Hale, Esq.

DEAR SIR:—I received duly your very kind letter of the 14th ult., and I beg to thank you for the honor you have done me in asking me to contribute to your ASTRO-PHYSICAL JOURNAL. I shall be only too glad to do so whenever I have the means. But the nature of my work in the College leaves me without much leisure for writing.

I shall value THE JOURNAL very much, as most of my work at the observatory is with the spectroscope. And if you will kindly inform me, I shall be glad to be a subscriber.

. . . . . .

Yours very truly,

WALTER SIDGREAVES.

MEUDON, France, Oct. 31, 1891.

DEAR SIR:—I am much pleased to learn that you have decided to publish the journal on spectroscopy you mentioned in your last visit to Meudon. I think that such a work, conducted by so able and enthusiastic a worker as yourself, will certainly prove of great assistance to spectroscopists, as well as it will materially assist in developing this branch of science.

I will take great pleasure in occasionally contributing papers on my line of research.

Very truly yours,

E. L. TROUVELOT.

WORCESTER, Mass., Nov. 27, 1891.

My Dear Mr. Hale:—

I am very glad to learn of the enterprise you have in hand, and shall be very happy to contribute anything of my own work which may pertain to the subject.

You are quite welcome to reprint anything of mine which has been published, but the results which I communicated to you in New York have not yet appeared in print, and—while I have not the slightest objections to your making any use you please of the rather rambling statements I then made—I shoi ld hardly like to publish anything *yet*, over my own name; though I may be in a position to do so in a few months.

With kind regards, and most cordial wishes for the success of the new enterprise,

I am, Sincerely yours,

ALBERT A. MICHELSON.

JOHNS HOPKINS UNIVERSITY, Baltimore, Oct. 17, 1891.

Professor Geo. E. Hale, Kenwood Physical Observatory, Chicago, Ill.

MY DEAR SIR:—Your letter of the 12th inst. was duly received.

I think your idea of publishing a journal specially devoted to spectroscopic work is a capital one. Not only will it be of great benefit to the investigators themselves; but it will also serve to interest others in this, one of the most fruitful and attractive fields of Physics. I shall do all in my power to further your interests.

. . . . . .

Most sincerely yours,

JOSEPH S. AMES.

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1416 K St., Washington, D. C., Oct. 26, 1891.

DEAR SIR:—I am pleased to learn that we are to have in the United States a journal devoted to Astro-Physics, and I assure you that I shall be very glad to contribute any papers that may arise from my work, unconnected with official duties, which may be connected with this subject.

. . . . . .

Yours truly,
FRANK H. BIGELOW.

RUSTHALL HOUSE, Tunbridge, Welis, October 31, 1891.

Professor George E. Hale,

DEAR SIR:—I fully appreciate your object in bringing out "THE ASTRO-PHYSICAL JOURNAL," and if able to forward that object at any time, I will gladly do so. With kind regards, I remain Yours very truly,
FRANK MCCLEAN.

7, KENSINGTON PARK GARDENS, London, W., Nov. 2nd, 1891.

To Professor G. E. Hale, Kenwood Physical Observatory, Chicago, U. S. A.

MY DEAR SIR: I am glad you are going to bring out the "ASTRO-PHYSICAL JOURNAL," and I shall await the first number with great interest. I think it will fill a gap in our scientific literature. . . . . .

With kind regards, believe me,
Very truly yours,
WILLIAM CROOKES.

DISTRIBUTION OF ENERGY IN STELLAR SPECTRA.*

PROFESSOR E. C. PICKERING.

FOR ASTRO-PHYSICS.

The relative brightness of stars or other luminous objects of different colors cannot be correctly indicated by any single number or ratio. It is necessary to employ a curve or series of numbers which shall give a measure of the energy of rays of each different wave-length. Stellar magnitudes only have a value so long as we can neglect the differences in distribution of the light according to the wave-length. Therefore when we compare the results of different processes, as photography and visual observations, entirely different results will be obtained for objects of different colors. If, however, we deal with rays of a single wave-length, all methods should give the same relative intensities. The intensities of rays of different wave-lengths may be determined by comparing the densities of different portions of a photographic spectrum. But large corrections must be applied for various sources of error for rays of each wave-length. Among these may be mentioned the absorption of the earth's atmosphere, the absorbtion of the prisms and lenses, the unequal sensitiveness of the silver salts, and the dispersion of the prisms by which the violet

* Communicated by the author.

rays are spread over a larger surface than the red rays. The direct determination of all these quantities would be a matter of no little difficulty. Fortunately this problem is greatly simplified by making the measures differential and comparing them with the elaborate determination of the distribution of the energy in the solar spectrum made by Professor Langley with the bolometer. He was aided in this research by Professor F. H. Very, and has kindly furnished approximate values of their results, from which the quantities given in the accompanying table are derived. The values of the wave-lengths are given in the first column, and the logarithm of the corresponding amount of energy in the second. The unit of energy is here assumed to be that of the hydrogen line G, this point being selected since it is near the center of the photographic spectrum. Instead of the usual logarithmic expressions corresponding to numbers less than unity, the equivalent negative expressions have been used. Thus —.26 is substituted for 9.74, etc. to make the table conform to the usual method of representing negative quantities. They can thus be readily converted into intervals on the scale of stellar magnitudes if desired by dividing by 0.4. Thus the logarithmic interval —.26 would correspond to .65 of a unit of stellar magnitudes.

From the collection of photographs of stellar spectra forming part of the Henry Draper Memorial nine were selected, all taken under similar conditions. They represent α Virginis, γ Cassiopeiæ, α Canis Majoris, α Canis Minoris, α Aurigæ, Saturn, α Tauri, α Orionis, and the sun. The spectrum of α Virginis is of the first type, but the Orion lines are well marked; γ Cassiopeiæ contains bright lines; α Canis Majoris is a typical first type star; α Canis Minoris is intermediate between the first and second types; α Aurigæ is of the second type; Saturn's spectrum closely resembles that of our sun, so also does that of α Bootis; α Orionis is of the third type, or intermediate between the second and third. The spectrum of the sun was obtained by reflecting its rays through a narrow slit and then rendering them parallel by means of a concave mirror having an aperture of 15 inches and a focal length of 150 inches.

Measures were then made by Mrs. Fleming of twenty points in each of the spectra, by comparison with a standard photographic wedge (Harvard Observatory Annals XXVI, p. 6). These measures were converted into logarithmic intervals, and the measure corresponding to the wave-length 434, which is that of the hydrogen line G, was subtracted from each. The values of the logarithm of the energy of the solar light taken from the sec-

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ond column of the table was next subtracted. The remainder will show the excess or deficit of energy of the star as compared with that of the sun, eliminating the various sources of error enumerated above. Finally the observed points were plotted and smooth curves were drawn through them. From these curves the values were found for each of the wave-lengths given in the table. The results for the various stars observed are given in the successive columns of the table. Thus in the case of α Orionis the energy for the wave-length 390, or near the line α, is —.57 as compared with that of sunlight. The numerical ratio is 0.27, whose logarithm is 9.43. The absolute energy is found by adding the tabular number to that given for sunlight in the second column. Thus —.26 —.57 = —.83, corresponding to the ratio 0.15. In the case of α Orionis, therefore, the energy of the light of wave-length 390 is only about one-seventh of that of wave-length 434. The numerical values of the energy of sunlight are given in the last column of the table. It therefore equals the anti-logarithm of the second column.

λ	log. E.	α Virg.	γ Cass.	α Can. Maj.	α Can. Min.	α Aur.	α Saturn	α Tauri.	α Ori.	E.
390	—.26	+.32	+.25	+.37	+.07	+.32	—.36	—.35	—.57	.55
400	—.19	+.14	+.10	+.10	—.04	+.08	—.20	—.14	—.38	.65
410	—.12	+.04	+.03	+.01	—.03	+.03	—.11	—.04	—.23	.76
420	—.07	.00	+.01	.00	—.01	+.01	—.06	—.02	—.11	.85
430	—.02	.00	.00	.00	.00	.00	—.02	.00	—.02	.95
440	+.02	+.01	.00	—.01	+.01	.00	.00	+.01	+.05	1.05
450	+.06	+.01	.00	—.02	+.01	—.01	+.01	+.02	+.10	1.15
460	+.09	—.04	.00	—.03	—.03	—.03	+.03	+.02	+.10	1.23
470	+.12	—.17	—.04	—.10	—.10	—.09	+.04	—.01	+.08	1.32
480	+.14	—.37	—.14	—.21	—.23	—.22	+.03	—.12	+.03	1.38
490	+.16	—.59	—.26	—.35	—.40	—.36	+.02	—.26	—.04	1.45
500	+.18	—.83	—.39	—.51	—.61	—.51	+.01	—.43	—.12	1.51
510	+.20	—1.10	—.54	—.71	—.84	—.67	.00	—.63	—.21	1.58

In the case of sunlight, a small correction should be applied for the selective reflection of the silvered glass mirror. This effect does not appear to be large, since the spectrum of Saturn gives nearly the same results as that derived from direct sunlight, except for rays of short wave-lengths. The negative values derived from these rays in the case of Saturn may be due to the selective reflection above mentioned. The corresponding residuals of the other spectra might be corrected by the amount thus indicated. Perhaps, however, Saturn is really bluer than the sun, in which case the values already given are correct. The curve for α Aurigæ is nearly the same as that of α Canis Majoris which shows that although its lines are the same as those of the sun, the distribution of its light resembles that of a first type star.

The red color of α Tauri and α Orionis as compared with α Virginis and α Canis Majoris is clearly shown by the change in sign of the residuals.

OBSERVATORY OF HARVARD COLLEGE,
Cambridge, Mass., U. S. A., October 31, 1891.

SPECTRUM OF β LYRÆ.*

PROFESSOR EDWARD C. PICKERING.

The spectrum of the variable star, β Lyræ, is unlike that of any other star hitherto examined. With the aid of Mrs. M. Fleming and Miss A. C. Maury a careful study has been made of twenty-nine photographs of this object. These photographs form part of the Henry Draper Memorial. The images on four other plates were too indistinct to be used and were not included in the following discussion. The spectrum is traversed by broad dark bands due to hydrogen and also by other lines characteristic of many stars in the constellation of Orion and forming that division of the first type which is designated as B in the Draper Catalogue. But besides these several bright lines are visible which change their positions. The most conspicuous of them have the approximate wave-lengths 486, 443, 434, 410, 403, and 389. The first, third, fourth and sixth of these apparently coincide with the hydrogen lines *F*, *G*, *h* and α. The others are two of the most marked of the Orion lines. The bright lines sometimes have a slightly greater wave-length than the corresponding dark lines, so that the latter sometimes appear to have bright edges on the less refrangible side while at other times the reverse is the case.

It is obviously desirable to trace any connection which may exist between these changes and the variations in the brightness of the star, the principal minima of which occur at regular intervals of about $12^d\ 22^h$. There are two maxima occuring at $3^d\ 5^h$ and $9^d\ 16^h$ after the principal minimum and an intermediate minimum following it $6^d\ 11^h$. Of the eleven plates in which the bright lines had a diminished wave-length it was found that all had been taken during the second half of the period of variation, that is after the second minimum and more than $6^d\ 11^h$ after the principal minimum. The fourteen plates taken during the first half of the period all showed an increase in wave-length of the bright lines, that is, the dark lines appear bright on the side

* *Astr. Nach.* 3051.

towards the red. There are, however, three exceptions, plates at $6^d\,13^h$, $7^d\,12^h$ and at $11^d\,11^h$ show an increased instead of a diminished wave-length. A re-examination of these three plates showed that the deviation of the lines was not very marked, and two other plates taken near the two minima showed a tendency of the lines to occupy an intermediate position and sometimes apparently to fall on the dark lines so as to nearly disappear.

Since the observations extend over more than four years or 130 periods of variation of the star, this latter period must coincide, or at least agree very closely with the period of change in the lines. It seems probable that they are due to the same cause. It should be noticed, however, that bright lines are not visible in the spectra of other variable stars of short period. The spectrum of S Monocerotis is of the Orion type, with dark lines resembling those in the spectrum of β Lyræ; ζ Geminorum, X Sagittarii, V Sagittarii, η Aquilæ and δ Cephei have spectra of the second type and the spectrum of T Vulpeculæ is intermediate between the first and second types.

The actual changes in the spectra when studied in detail are much more complicated than has been stated above and show a variety of intermediate phases, and changes in the dark as well as in the bright lines. In some of the photographs several of the bright lines appear to be double. Micrometric measures are now in progress, additional photographs are being taken, and a complete study of the whole will be made.

The most natural explanation of the motion of the bright lines is that the object emitting them is revolving in a circular orbit having a period of $12^d\,22^h$. The maximum velocity is approximately 300 English miles (500km). The corresponding minimum value of the radius of the circle would be about 50,000,000 miles. Perhaps this object is a close binary resembling β Aurigae but with components having unlike spectra. The phenomena may also be due to a meteor stream, or to an object like our sun revolving in $12^d\,22^h$ and having a large protuberance extending over more than 180° in longitude. The occasional doubling of the lines would then be due to both ends of the protuberance being visible at the same time, one receding, the other approaching. The variation in light may be caused by the visibility of a larger or smaller portion of this protuberance.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., June 29, 1891.

STARS HAVING PECULIAR SPECTRA. NEW VARIABLE STAR IN LACERTA, DM + 39°.4851.*

M. FLEMING.

A photograph taken at this Observatory on July 6, 1891, shows that the hydrogen lines *G* and *h* are bright in the spectrum of a third type star DM. + 39°.4851 Magn. 8.8, whose approximate position for 1900 is in RA. $22^h\ 24^m.7$, Decl. + 39° 48′. As this has been assumed to be a distinctive feature in the spectrum of variables of long period, charts of the region containing this star were examined and measured. The charts were taken on Nov. 6, 1889, August 6, 1890, July 9, and July 13, 1891, and the approximate magnitude of the star on these respective dates was $<$12.9, 12.7, 9.5, and 9.9. The estimated magnitude on the spectrum plate from which the star was discovered is 9.7. The variability of this star is thus confirmed. — The variable star in Hydra, announced in the Astr. Nachr., Bd. 126, p. 117, was in declination —27° 52′ and is W Hydræ, which had been previously announced by Mr. E. F. Sawyer in the Astronomical Journal, Vol. IX, p. 94. — In the Astr. Nachr., Bd. 127, p. 5, the new variable star in Aquarius is given as in RA. $20^h\ 41^m.3$ and should be RA. $20^h\ 43^m.1$ for 1900. — Several photographs have been obtained of the spectrum of DM. —10°.5057, Magn. 7.0, whose approximate position for 1900 is in RA. $19^h\ 17^m.7$, Decl. —10° 54′. The star was supposed to be of the fourth type and was announced in the Astr. Nachr., Bd. 126, p. 163, but in later photographs more marked peculiarities are seen. The lines in the spectrum are not those due to hydrogen. In some photographs they are broad bands, while in others the lines appear to be double. No other star has yet been found here whose spectrum resembles that of this object. As the stellar magnitude is 7.0 a large dispersion cannot be used. A visual examination with the 15-inch equatorial telescope failed to show the peculiarities mentioned above. — The nebula, G. C. 844, whose approximate position for 1900 is in RA. $4^h\ 17^m.8$, Decl. —55° 11′, is well shown on a photograph taken at Mt. Harvard, Peru, on Sept. 8, 1890. Two well marked spiral rays surround the stellar nucleus, the preceding one turning through about 240°, the following one through about 130°.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., July 23, 1891.

* Communicated by Edward C. Pickering, Director of Harvard College Observatory, to *Astr. Nach.* 3054.

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THE MODERN SPECTROSCOPE.

Within the past few years some very important advances have been made in the construction of spectroscopes. In few cases, however, have the details of instruments been minutely described, and the merits and demerits of the various types are not very generally known. For this reason it has been considered desirable to publish a series of papers on "The Modern Spectroscope," in which the most important instruments now in use will be examined in detail. The concave grating is described by Dr. Ames in the first paper of the series. Professor Keeler is preparing an article on the Lick Spectroscope for our February number, and others of equal interest will follow.

*The Concave Grating in Theory and Practice.**

By Joseph Sweetman Ames, Ph. D., Associate in Physics in the Johns Hopkins University, Baltimore.

The following paper is in the main a reprint of an article with the same title in the Johns Hopkins University Circulars, No. 73, May, 1889, which afterwards appeared in the Philosophical Magazine, May, 1889. It gives the general theory of the instrument and its adjustments, and a full description of the apparatus in use in Professor Rowland's laboratory at the Johns Hopkins University.

General Theory.

The theory of a concave spherical grating gives (See Rowland, *Phil. Mag.*, vol. XVI, p. 197, and *Amer. Jour. Sci.*, vol. XXVI, p. 91) as the radius vector of the focal curve, referred to the center of the grating as origin (see Fig. 1).

$$r = \frac{R\rho \cos^2 \mu}{R(\cos \mu + \cos \nu) - \rho \cos^2 \nu}$$

μ is the angle r makes with ρ the radius of curvature of the grating; and R and ν are the coördinates of the source of light. For any given value of R and ν there is a curve defined by r and μ, on which the various spectra are brought to a focus; and there is a second curve passing through R, ν, such that, if the source of light be placed at any point of it, the spectra will be brought to focus along the curve r, μ. These two curves are, then, conjugate, and their properties have been discussed by Mr. Baily in the *Phil. Mag.* for 1883.

* Communicated by the author.

If we make $R = \rho \cos \nu$, *i. e.*, place the slit on the circle whose diameter is the radius of curvature of the grating, $r = \rho \cos \mu$. Hence the two focal curves coincide. This case is shown in Fig. II.

As is well known this arrangement is mechanically secured by placing the slit at the intersection of two beams set at right angles, on which are ways to carry the grating and eye-piece, these two being kept at a constant distance ρ apart by an iron girder. Or, the grating and camera box may be kept fixed, and the slit moved along a circular track. The former method is in use generally. Thus: in Fig. III the slit is at A, the grating at B, and the eye-piece or camera at C.

The reasons for putting the eye-piece at C, where $\mu = 0$, are easily found. Imagine the micrometer screw carrying the eye-piece, to be placed at D, Fig. IV, tangent to the focal-circle. Let the eye-piece be displaced along the tangent by an amount $\overline{DD'}$ or "a."

$$a = \frac{\rho}{2} \sin 2(\mu - \theta)$$

da = one turn of micrometer

$$= \rho \cos 2(\mu - \theta)\, d\mu = \Delta$$

But by theory of diffraction (see Rayleigh, *Encyc. Brit.*, Wave Theory of Light, vol. XXIV, p. 437)

$$\lambda = \frac{\omega}{N} (\sin \nu + \sin \mu)$$

where ω is grating space and N the order of spectrum

$$\therefore d\lambda = \frac{\omega}{N} \cos \mu\, d\mu = \frac{\Delta\omega \cos \mu}{N\rho \cos 2(\mu - \theta)}$$

Or, if a photographic plate, bent to radius $\rho|_2$, were placed at D, one scale division Δ along plate

$$= \rho\, d\mu$$

$$d\lambda = \frac{\omega}{N} \cos \mu\, d\mu$$

$$= \frac{\Delta\omega}{N\rho} \cos \mu$$

Now, if $\theta = 0$, *i. e.*, if the micrometer eye-piece or the camera-box be placed perpendicular to the arm $\overline{BC}$, we have

$$d\lambda = \frac{\Delta\omega}{\rho N}$$

since μ is so small that we can put $\cos \mu = 1$. Hence the spectrum is "normal" at C. Further, in this case,

$$\lambda = \frac{\omega}{N} \sin \nu$$

$$\therefore \text{since } AC = \rho \sin \nu$$

$$\lambda = \frac{\omega}{\rho N} \overline{AC}$$

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Thus, if one absolute wave-length is known, and if the instrument is in perfect adjustment, we can mark on the beam $\overline{AC}$ a scale of wave lengths for each spectrum, and the absolute wave length of any line is known at once. It is important to notice that this scale on the beam is identical with the scale on the photographic plate, and that all the spectra are in focus at C at the same time, and *stay in focus* however C moves along $\overline{AC}$, it being rigidly fastened to B. These facts alone would render a concave grating preferable to a plane one; but it has many other points of superiority. It is the only spectroscope suitable for use in both the ultra-violet and the infra-red. Much longer photographic plates can be used than with any other instrument, since they can easily be bent so as to be entirely in focus. Between the slit and the camera-box, no lens is interposed. Besides saving in light and cost, there are no corrections necessary for spherical aberration, imperfections of lenses, right and left handed quartz, etc. Further, the concave-grating is *astigmatic*, *i. e.*, a point of light as the source is brought to focus not in a point, but in a line. The advantages of this fact are:

1st. A narrow spark at the slit is broadened into a wide spectrum.

2d. Greater accuracy in comparing metallic and solar lines is secured, as will appear later when the use of the instrument is described.

3d. There are no "dust-lines," for they are brought to a different focus.

4th. A spectrum is obtained which is broad enough to stand enlarging.

Theory of Errors in Adjustment.

The mounting of the slit, grating and camera-box on the circumference of a circle of radius $\frac{\rho}{2}$ passing through the center of the grating, is the ideal one. In practice it is impossible to attain it; and so it becomes necessary to study the effect of any small displacement from the perfect adjustment.

I. Let ρ be slightly less than the fixed arm $\overline{BC}$. Fig. V.

$$BC = a$$

$$BD = \rho$$

We wish to find r in the neighborhood of $\mu = 0$

$$\therefore r = \frac{\rho R}{R + R\cos\nu - \rho\cos^2\nu}$$

But we keep $R = a\cos\nu$

$$\therefore r = \frac{\rho a}{a + a\cos\nu - \rho\cos\nu}$$

$$\text{Let } a = \rho(1+\theta) \qquad i.e., \theta = \frac{CD}{DB}$$

$$r = \rho\,\frac{1+\theta}{1+\theta(1+\cos\nu)}$$

If θ is small

$$r = \rho(1 - \theta\cos\nu)$$

Let the camera-box be placed in focus when $\nu = 0$; its distance from the grating is then $\rho(1-\theta)$ $\therefore$ the distance it is out of focus for any position ν is $y = \rho(1-\theta\cos\nu) - \rho(1-\theta) = \rho\vartheta(1-\cos\nu)$ $= a\vartheta(1-\cos\nu)$

Put $\overline{AC} = x = a\sin\nu$

$$\therefore y = a\vartheta - \vartheta\sqrt{a^2 - x^2}$$

This is the equation of an ellipse having center at $(0, a\vartheta)$ and having as semi-axes a and $a\vartheta$. Fig. VI.

II. Let the slit be slightly displaced from A along $\overline{AB}$. Fig. VII.

$$BD = R$$
$$AD = b$$

As before

$$r = \frac{\rho R}{R + R\cos\nu - \rho\cos^2\nu}$$

But $\rho\cos\nu = R + b$

$$\therefore r = \frac{\rho^2 R}{\rho R - Rb - b^2}$$

$$\text{Let } \frac{b}{\rho} = \alpha, \text{ a small quantity}$$

$$\therefore r = \rho(1+\alpha)$$

for all values of R removed from 0, as it always is in practice.

Hence, if the camera-box is once put in focus, it stays so, wherever it is moved along $\overline{AC}$.

III. Let the two beams $\overline{AB}$ and $\overline{AC}$ make an angle $\pi|_2 - \vartheta$ with each other. Fig. VIII.

As before

$$r = \frac{\rho R}{R + R\cos\nu - \rho\cos^2\nu}$$

And $\rho\cos(\nu - \vartheta) = R\cos\vartheta$

$$\therefore \rho\cos\nu = R - \rho\sin\nu\tan\vartheta$$

$$\therefore r = \rho\,\frac{\rho R}{\rho R + R\rho\sin\nu\tan\vartheta} \qquad \text{if } \vartheta \text{ is small}$$

$$= \rho(1 - \sin\nu\tan\vartheta)$$

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If camera-box is put in focus when $\nu = 0$, it will be out of focus at any point an amount, $y = \rho(1 - \sin\nu \tan\vartheta) - \rho = -\rho \sin\nu \tan\vartheta$.

$$\text{But } x = \overline{AC} = \rho \frac{\sin\nu}{\cos\vartheta}$$

$$\therefore y = -x \sin\vartheta = -a \tan\vartheta$$

the equation of a right line making an angle ϑ with axis of x. Fig. IX.

IV. Let the grating be turned on its axis so that its radius of curvature makes a constant angle α with the arm BC. Fig. X.

$$BD = \rho$$
$$BC = a$$

Since μ is kept equal to α

$$r = \frac{R\rho \cos^2\alpha}{R(\cos\alpha + \cos\nu) - \rho\cos^2\nu}$$

But $a\cos(\alpha + \nu) = R$

$$\therefore r = \rho \frac{a\cos(\alpha+\nu)\cos^2\alpha}{a\cos(\alpha+\nu)(\cos\alpha + \cos\nu) - \rho\cos^2\nu}$$

Put $a = \rho(1 + \delta)$, and suppose both α and δ to be small. Then

$$r = \rho(1 + \alpha\sin\nu - \delta\cos\nu)$$

Let the camera-box be placed in focus when $\nu = 0$; the distance it is out of focus at any point is then

$$y = \rho(1 + \alpha\sin\nu - \delta\cos\nu) - \rho(1 - \delta)$$
$$= \rho(\alpha\sin\nu + \delta - \delta\cos\nu)$$
$$x = a\sin(\alpha + \nu)$$
$$\therefore y = \alpha x + a\delta - \delta\sqrt{a^2 - x^2}$$

Since α and δ are both small, this curve is the sum of those found in Cases I and III.

Case V. Let the slit be displaced along $\overline{AC}$. See Fig. XI.

We have

$$AD = b$$
$$DC = x$$

As before

$$r = \frac{\rho R}{R + R\cos\nu - \rho\cos^2\nu}$$

But $R^2 = \rho^2 - x^2 - 2bx$

$$\text{and } \cos\nu = \frac{\sqrt{\rho^2 - x^2}}{\rho}, \text{ since } \frac{b}{\rho} \text{ is small}$$

$$\therefore r = \rho\left\{1 + \frac{bx}{\rho\sqrt{\rho^2 - x^2}}\right\}$$

$$y = r - r_{\nu=0} = \frac{bx}{\sqrt{\rho^2 - x^2}}$$

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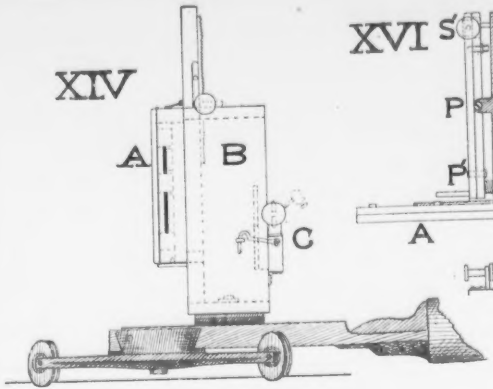
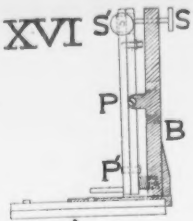
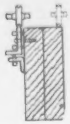
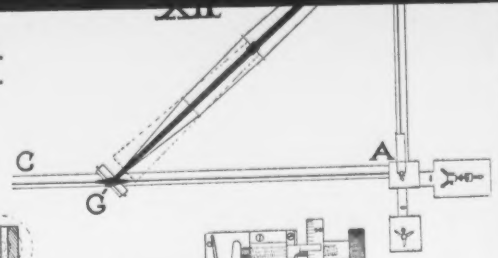
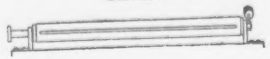
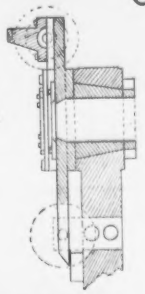


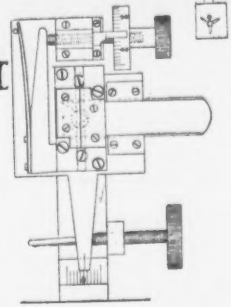




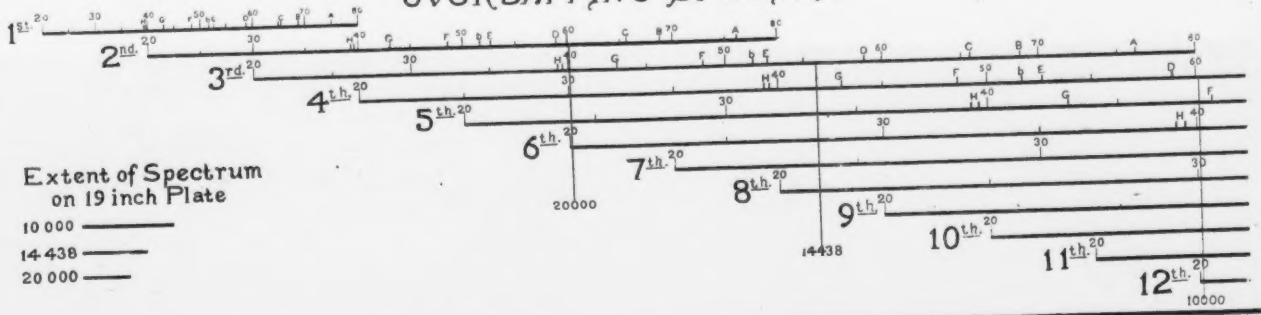






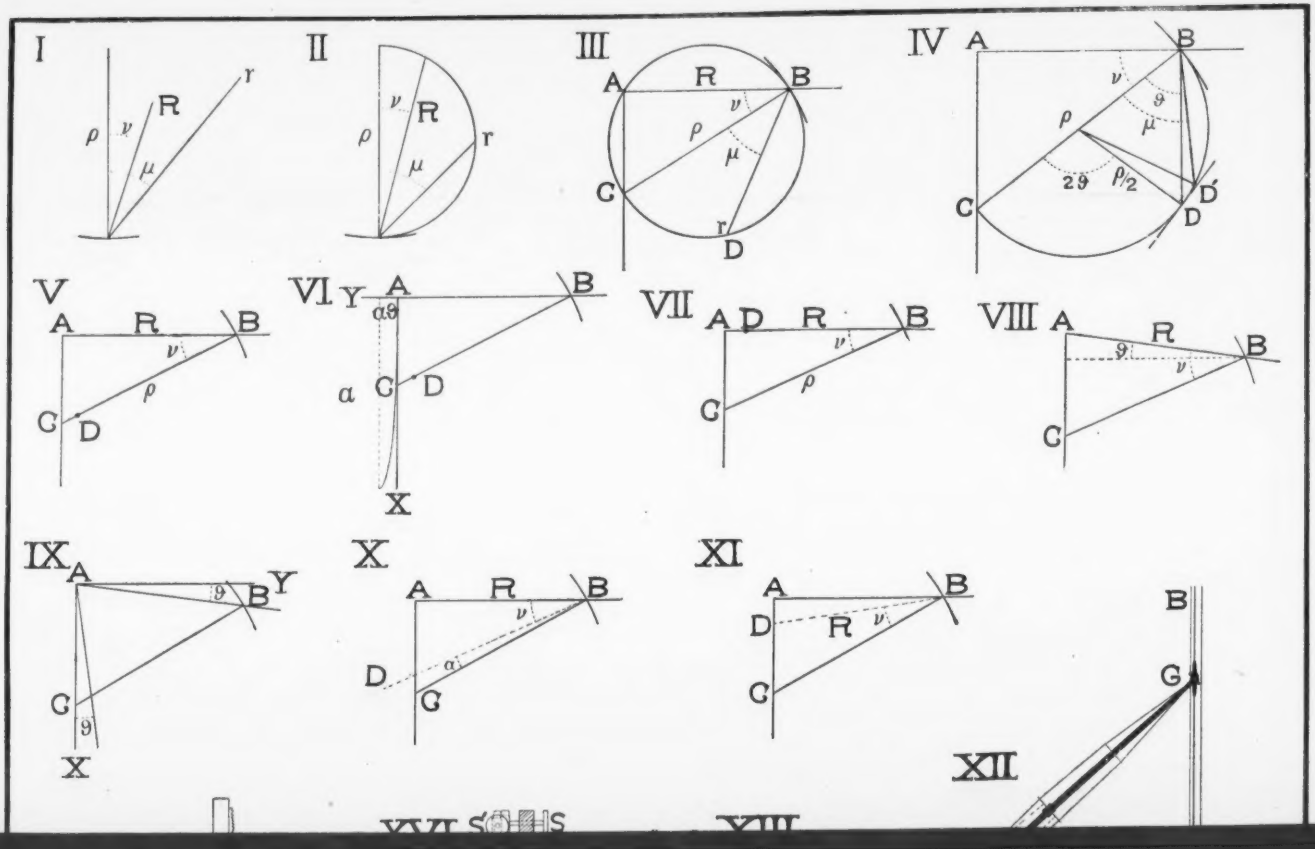


OVERLAPPING SPECTRA



Extent of Spectrum
on 19 inch Plate

10 000 ——
14 438 ——
20 000 ——


I
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XII
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By the principle of addition of small displacements, the effect of any combination of these *five* displacements can be found by addition—one can be used to counteract another, and so on. Thus, displacement IV can correct a combination of I and III. This has been found true in practice.

Any small displacement, provided that the distance from the grating to the camera box is unaltered, does not affect the constant of the instrument (*i. e.* the ratio of Δ to $d\lambda$) for, as we saw above, that depends on this distance alone.

General Description.

Before giving the adjustments and precautions necessary in mounting a concave grating properly, I will briefly describe the various parts of the apparatus as used in Professor Rowland's Laboratory.

The instrument is mounted in a room, the walls and fixtures of which are blackened, and whose windows are of "ruby" glass and provided with black shades. Opening off this is a balcony for the heliostat. The beams, carrying the instrument are placed about eight feet from the floor, and a platform erected at one end of the room, thus allowing the floor space to be used for other purposes, if necessary.

AB and *AC* (see Figs. XII, XIII) are heavy wooden beams 6×13 in. and 23 feet long. *AB* is fastened rigidly to the wall, while *AC* has a slight freedom of rotation about *A*, controlled by screws at *C*. The "ways" for the grating-holder and camera-box are fastened to these beams by screws which admit of adjustment, so that they may be straightened if the beams warp. They are made of ½ inch angle-iron, although a board made of any hard wood may be used. *GG'* is a 4 in. tubular wrought-iron girder, braced by a truss, and pivoted at its ends, directly over the "ways," on two iron carriages. Its length is approximately equal to the radius of the grating, and has a range of adjustment of about six inches. The carriages have each two brass wheels or rollers placed nearly a foot and a half apart, and these resting on the iron ways enable the girder to be easily moved from one position to another. The camera-box *G'* and grating-holder *G* are themselves moveable along *BC* and have freedom to revolve around axes, but can be finally clamped in place.

The camera-box (see Fig. XIV) consists of a fixed wooden frame *B*, and a box *A* which can be removed. The sensitive plate is placed in *A* in suitable slots and is pressed firmly by means of

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wooden buttons against pieces of hard rubber so that it is bent to the proper radius. There is in *B* a frame which can be moved vertically by a rack and pinion; and to this *A* is fastened by dowel pins on the bottom and hooks at the top. On the back of the camera-box, *B*, is hinged a board "*C*," which can be held firmly in place by hooks. This board carries a brass plate (see Fig. XV) having a longitudinal opening of a width equal to the thickness of the plate itself and capable of revolution around a horizontal central axis. By means of stops this revolution is confined to 90°. This plate is used for the comparison of spectra, as described below.

The grating-holder is made of brass. It consists (see Fig. XVI) of a heavy platform carrying an upright frame, *B*, which can move in slots on *A*. To *B* is fastened by screws at the sides, *P*, a square piece of brass *D*. *D* is moveable around the axes, *P*, by means of a screw, *S*. To *D* by means of an axis, *P'*, at the bottom is fastened the frame *C*. By means of a screw at *S'* whose nut is rigidly connected with *D*, *C* can be moved around the axis, *P'*. Springs take up the slack of the screws when unscrewed.

The grating itself stands on two projections at the bottom of *C*, and is held there, *free from all constraint*, by a soft wax. By means of the side and back screws the grating can, then, be turned around its centre in its own plane, or tipped back and forward.

The slit, placed at *A*, is of somewhat complicated mechanism. See Fig. XVII. It has the following adjustments:

1st. Width of slit can be regulated by a micrometer screw. It is generally not open more than 0.001 in.

2d. The slit can be rotated about a central axis so as to make it parallel to the lines of the grating. This adjustment is one of the last to be made in mounting the grating, and is done by turning the slit until the definition is the best possible. This is most important, as the excellence of the photographs depends largely upon it. The definition is spoilt, if the slit is 0°.5 out.

3d. Stops can be inserted at top and bottom, thus causing the grating to be illuminated by the center of the solar image only. Otherwise the definition may be spoilt by the rotation of the sun. It is important, therefore, that the image of the sun on the slit be quite large. With the larger apparatus in use in the Johns Hopkins University it is 1.2 cm. in diameter, and this is reduced one-half by the stops.

For solar work, a heliostat, having a south-exposure, throws

the light on the slit by means of a condensing lens and a totally reflecting prism. The lens is held in a brass frame, and can be adjusted from within the building. Between the prism and the lens is a revolving stage with circular openings, across which absorbing solutions can be placed. Both this stage and the lever arm carrying the reflecting prism are controlled by strings running along $\overline{AC}$; so that, without leaving his seat, the observer can place different solutions before the slit, or put aside the prism, when a metallic spectrum is to be photographed. For this *last* purpose, along the line of the slit and grating, is a wooden tube with condensing lens, which focuses on the slit the image of the arc-light or spark, placed in a separate compartment. See Fig. XII. All lenses and prisms must, of course, be made of quartz.

For the arc-light a Weston dynamo of 150 volts, 30 amperes power is used, or an alternating Siemens of 700 volts maximum. For spark spectra, Professor Rowland has constructed an induction coil, which (with from 3 to 12 gallon jars) gives a spark of intense brilliancy, when driven by the alternating Siemens dynamo. Using this coil, iron wire of $\frac{1}{16}$ in. diameter melts, and $\frac{1}{8}$ in. wire is heated red hot.

Gratings with 10,000, 14,438, and 20,000 lines to the inch are used. For ordinary purposes a 10,000 one is sufficient, while for photographing in the ultra violet it is best to have a 20,000 grating, with a ruled space of 5½ in. on a 6 in. polished surface. The radius of curvature is generally 21.5 ft. The photographic plates are 19 in. long, 2 in. wide, and $\frac{1}{14}$ in. thick. This thickness allows the plates to be bent to the required radius without breaking. They are flowed with an ammonia emulsion by Professor Rowland himself, and register from 15–20 on Warnerke's sensitometer. Quick plates give too coarse an effect for enlargement. For short focus gratings, such as are used for gaseous spectra and direct stellar spectra, microscope-slide glass is necessary.

The micrometer eye-piece used is more like a dividing engine than an ordinary micrometer. It has a run of 5 inches, and the screw is to all purposes perfect, having been made according to the directions given by Professor Rowland in his article on the Screw in the *Encyc. Brit.*, Vol. XXI, p. 552.

Hoods of black cloth to keep out stray light are necessary at the slit, and at the camera-box where one should extend half way to the grating, as even the darkest room has some light in it.

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Adjustments.

The adjustment of these various parts of the apparatus is comparatively simple. The two beams carrying the grating and camera-box are made as level as possible and placed at right angles by the "3, 4, 5" rule. The two axes at the ends of the girder must be made parallel, *while the girder is under stress.* To do this the girder is supported at its ends on two "horses;" and the axes are adjusted by the control-screws until the two are vertical. This is the most difficult adjustment.

The camera-box, grating-holder, and slit are put in place at the proper height. Most gratings give a brighter spectrum on one side than on the other; and so, before placing the grating on its holder, it must be examined to see which side should be used. The grating is then placed in position, free from constraint; and a candle is held at the center of the camera-box, directly over the axis of the carriage. The grating is turned and the girder lengthened until the flame and its image coincide. By this, the grating is placed perpendicular to the girder, and the girder itself is given the correct length. The camera box is then made vertical by a plumb-line. To adjust it perpendicular to the girder, a piece of plate glass is fastened to its face, and a candle is held on the girder near the grating. The camera-box is then revolved until the flame and image come in line. The reflecting prism is now put in place so as to illuminate the *entire* grating, and the slit opened. The spectrum formed at the camera-box is observed by the eye, or thrown on a piece of paper; and the back-screw of the grating-holder is turned until it falls at the right height. The camera-box is moved to the right or left, and in general the spectrum rises or falls. This is corrected by the side-screw of the grating holder. These two adjustments are repeated many times until the spectrum stays in place however the camera-box is moved. Then the slit is narrowed, and revolved until the best definition is secured. The instrument now should be in perfect adjustment, and, to test this, an exposed photographic plate, off which the emulsion has has been partially scraped, giving it a lattice-work appearance, is put in the camera-box, emulsion side toward the grating. The spectrum formed on the plate and the emulsion itself ought now to be in focus at the same time in all orders of spectra; that is, if the plate is observed with an eye-piece, there should be no par allax between the two. In general further adjustment is found necessary. It was to this end that the theory of errors, as above, was deduced. Let the camera-box be placed in focus when it is

near the slit: and then, as it is moved away from it, suppose the parallax increases proportionally to the distance along the way. This would lead one to think that the two beams were not exactly at right angles. Similarly for the other displacements. It is found in practice that it does most good to turn the grating-holder slightly around its vertical axis.

If, in setting up the instrument, a micrometer eye-piece is used instead of a camera, practically the same adjustments are found necessary.

Use of Instrument.

Gratings in Practice.

Special gratings should be selected for special purposes. Every grating has spectra of different brightness on the two sides; and one should be used which is bright in the particular spectra desired. But more than this, even if the red of any one spectrum is bright, the violet may not be. This fact must be especially noted in working beyond the visible spectrum. Further, the various parts of the grating, especially if it is concave, may give spectra of varying brightness. For instance, the second spectrum may be uniformly bright for all parts of the grating, while one end of the grating may give a bright third spectrum and the other end a faint one. This fact may be brought out by viewing the grating directly with the eye. It is only when extreme accuracy is wished and the overlapping spectra of different orders are to be used that this imperfection must be guarded against. Since a 10,000 grating has on the whole better definition than a 20,000 one, and as it is much cheaper, it is better to use one in all cases when possible. For use with the micrometer eye-piece, when, of course, ultra-violet spectra do not interfere, one can always be used.

It is only when work is to be done with the camera in the ultra-violet part of the spectrum that it becomes necessary to use a 20,000 grating. This is due to the fact that for the same dispersion with a 20,000 grating as for a 10,000, there are fewer overlapping spectra. The range of concave gratings mounted as above are as follows:

Lines per inch	1st Spectrum	2d Spectrum	3d Spectrum	4th Spectrum	5th Spectrum
10,000	Entire	Entire	Entire	To 6,000	To 4,800
14,438	Entire	Entire	To 5,760	To 4,330	To 3,460
20,000	Entire	To 6,000	To 4,000	To 3,000	To 2,400

These limits are taken at the *center* of the photographic plate. At the end of the plate the limit is somewhat greater, being 6,260 in the second spectrum for a 20,000 grating.

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With a grating of 21.5 feet radius the width of the spectrum varies from ¼ in. to 4 in. In the green of the 1st spectrum of a 20,000 grating it is ¾ in., and in the green of the 2d it is 2⅝ in. This gives an idea of the width of the photographic plate which is required.

The scale of the negatives in the various spectra, with gratings of 21.5 feet radius, is as follows;

	Scale of Spectra as compared with Angström's map.			
Lines per inch.	1st.	2d.	3d.	4th.
10,000	.26	.51	.77	1.03
14,438	.37	.75	1.12	1.50
20,000	.52	1.03	1.55	2.07

i. e., using a 20,000 grating in the third spectrum, the scale is 1.55. This means that 1.55^{mm} on the photographic plate includes 1 Angström unit. For gratings of 10 ft. radius, the scale is diminished in the ratio of 100 : 215, or 20 : 43.

Since with a concave grating all the spectra are in focus at the same time, it is important to know what wave-lengths of the different spectra are on the photographic plate or in the field of the eye-piece for any position they may be in. For this purpose I have given a diagram of the overlapping spectra on the plate. This explains itself: Wave-length 6,000 in the 2d spectrum coincides with wave-length 4,000 in the 3d spectrum, with wave-length 3,000 in the 4th spectrum, and so on. The vertical lines give the range of the different gratings as explained above.

If it is desirable to cut off any interfering spectrum, glass plates or absorbing solutions may be used. A list of the principal absorbents, and the parts of the spectrum which they *let through*, is given below.

Greenish plate glass.....3,300–8,000
Salicylic acid in alcohol, saturated, in quartz cell.....3,500–8,000
Aesculin, 1 gr. in 1 oz. water, with one drop of Ammonia—fresh, 4,100–8,000
Potassium ferrocyanide.....4,400–8,000
Primrose or Anilide Yellow.....5,000–8,000
Fluorescine or Chlorine of Gold.....5,200–8,000
Chrome Alum, } 3,200–3,700
Malachite Green, } ..... and
Bitter-almond Green, } .....
Brilliant Green, } 4,600–5,200
Cobalt Chloride.....3,400–4,500
Gentian Violet, strong.....3,600–4,600 and 6,000–8,000
Potassium permanganate.....3,900–4,600 and 5,800–8,000

For example, using a 10,000 grating and photographing in the 4th spectrum, the following absorbing solutions are used at the places specified:

At 3,800 Cobalt Chloride in water.
4,000 Cobalt Chloride or Gentian violet in water in glass cell.
4,200 Potassium permanganate or Gentian violet in water.

4,400 Aesculin and Potassium permanganate.
4,600 Aesculin.
4,800 Aesculin and Malachite Green in water.
5,000 Aesculin and Potassium ferrocyanide.
5,200 Aesculin and Potassium ferrocyanide.
5,400 Aesculin and Primrose.

Before using a solution an observer should always see, by a preliminary experiment, what its effect is.

Methods of Work.

A spectroscope is used for two purposes, to measure the lines in solar or metallic spectra, or to establish coincidences simply. For both of these the concave grating is far superior to any other on account of the overlapping spectra.

The micrometer eye-piece, of course, can be used only in the visible spectrum, while the methods of photography give us this and the invisible too. Rowland's micrometer eye-piece, as noted above, has a run of five inches, and so it can include a great number of lines. When a metallic spectrum is to be measured, the solar spectrum is turned on; a series of measurements is taken; then the solar spectrum is replaced by the metallic; another series is taken; and finally the series of solar lines is observed again. All this is done without the observer leaving the eye-piece. The solar lines are found on Rowland's map, and then the wave-lengths of the metallic ones are deduced by interpolation. This same method of interpolation will also give the relative wave lengths of the solar lines using the over-lapping spectra. The probable error of a wave length determined this way is ± 0.01 Angström unit.

Now that we have Rowland's map and his list of solar lines, the photographic process for the measurement of metallic spectra is generally used as far as the erythrosin plates extend or to the *D* line, although those expert in the use of cyanine plates may photograph below *C* or even *A*, as Mr. Burbank has shown in the *Phil. Mag.* for Oct., 1888.

Owing to the astigmatism of the grating, it is not possible to adopt the usual method of illuminating part of the slit with the solar image, and part with the spark or arc; and so a different and far better plan is adopted. A compound photograph of the two spectra is taken in the following manner: The brass plate on the back of the camera-box (see Fig. XIV) is placed vertical, the solar spectrum is photographed along the middle of the sensitive plate, the sun-light is turned off, the brass plate is revolved through 90°, and the metallic spectrum is allowed to fall along the upper and lower parts of the photographic plate.

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Then finally the sun-light is turned on again along the middle of the plate. If there has been any gradual displacement of the camera during the operation, the error is eliminated by this process, if the two times of exposure to the solar spectrum are the same.

It is important to notice that record must in all cases be kept of thermometer and barometer readings; for the corrections due to variations in temperature and pressure may be considerable.

Since no absorbing solution is known which lets through the ultra-violet rays alone, the following method has to be used to determine what lines on any negative are ultra-violet ones. A compound negative, as just described, is taken, having all the overlapping spectra at the point in question along the middle of the plate and the visible lines alone, obtained by inserting absorbents, along the top and bottom. Those lines present in the first and not in the second are then ultra-violet ones.

For arc or solar light, five minutes exposure is the average time required for the most sensitive part, in the third spectrum on plates registering 18 on Warnerke's sensitometer. Ten minutes are required above the *D* lines in the second spectrum using erythrosin plates. One hour is needed for cyanine plates, photographing down to the *C* line. As a practical example, the entire iron and solar spectra were photographed in the second and third spectra from the *D* lines down to the extreme ultra-violet in nine hours. This includes time spent in developing. Thirty plates, each 19 inches long, were exposed, giving, of course, many duplicates. Only 10 plates are necessary in the 2d spectrum of a 20,000 grating for the whole spectrum from the *D* line to the extreme ultra-violet, wave length 2,000. In one case Liveing and Dewar used 170 plates for the ultra-violet spectrum alone.

With the powerful induction coil, worked by a Siemens alternating dynamo, with six gallon Leyden jars, 10 minutes is enough in the most sensitive part and 30 in the extreme ultra-violet, wave length 2,200.

A compound negative taken in the above manner is placed on a dividing engine; the pitch of the screw being one w. l. on the negatives and measurements are made on the lines of the two spectra, using a low power microscope with a single stretched cross-hair. Since the solar spectrum continues down to 3,200, the same orders of the two spectra can be compared thus far. Beyond this it is necessary to use different orders. For instance,

wave length 2,800 in the 3d spectrum can be compared with solar lines about wave length 4,200 in the 2d. This same method is used to determine the relative wave lengths of the solar spectrum.

To enlarge photographs with a scale of wave-lengths, like Rowland's map of the spectrum, one must proceed as follows:

To make the scale, a thick plate of glass, slightly longer than the negative, is albuminized and treated with collodio-chloride. It is then put in any developer until it turns black. A longitudinal strip of the width of the negative is scraped off; and on the edge of this strip the scale is ruled with a dividing engine. The negative is clamped in place to this scale, and together they are put in the enlarging camera. The accuracy with which the scale can be made, and the negative fitted to it is most satisfactory. On Professor Rowland's new map the greatest error is .03 of an Angström unit; and the probable error is less than .02 of a unit. If the scale is, say, .0001 too large or too small, the photographs can be made to fit the scale by altering the distance between the grating and camera-box by .0001 of its amount, and then focusing by moving the slit in or out.

When this scale is once made, it can be used to give direct readings for the wave-lengths of the lines on any negative, simply by placing the negative on the scale.

A word should be said as to the difficulties of ruling gratings which may explain why so many orders for gratings remain unfilled. It takes months to make a perfect screw for the ruling engine, but a year may easily be spent in search of a suitable diamond point. The patience and skill required can be imagined. Most points make more than one "furrow" at a time, thus giving a great deal of diffused light. Moreover, few diamond points rule with equal ease and accuracy up hill and down. This defect of unequal ruling is especially noticeable in small gratings, which should not be used for accurate work. Again, a grating never gives symmetrical spectra; and often one or two particular spectra take all the light. This is of course desirable, if these bright spectra are the ones which are to be used. Generally it is not so. It is not easy to tell when a good ruling point is found; for a "scratchy" grating is often a good one; and a bright ruling point always gives a "scratchy" grating. When all goes well, it takes five days and nights to rule a 6 in. grating having 20,000 lines to the inch. Comparatively no difficulty is found in ruling 14,000 lines to the inch. It is much harder to rule a glass grating than a metallic one; for to all of the above difficulties is

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added the one of the diamond point continually breaking down. For this reason, Professor Rowland has ruled only three glass gratings. One of them has been lost, and the other two are kept in his own laboratory. These two were used by Dr. Bell in his determination of the absolute wave-length of the *D* lines.

ON THE PHOTOGRAPHIC METHOD OF DETERMINING STELLAR PLACES BY TRANSITS FREED FROM THE ERROR OF PERSONAL EQUATION.*

PROFESSOR FRANK H. BIGELOW.

Some accounts of the preliminary experiments looking to the elimination of the error of personal equation from star transits by employing a photographic registration of the passage of the star over the reticle of the transit instrument, have already been published by those who have been engaged upon the work. Professor Pickering in the Memoirs of the American Academy, Vol. XL., p. 218, describes his breaking up a smooth star trail by alternating motions imposed upon a bit of photograph plate, and shows that by means of an auxiliary micrometer the instants of time can be determined in general to about 0.03 of a second. Mr. Willard P. Gerrish has described a commutator in THE SIDEREAL MESSENGER of October, 1889, by which the standard clock of an Observatory is enabled to give the required alternating motion to this plate, the duration of exposure in any position being regulated automatically. The Rev. Fr. Fargis, assistant in the Georgetown Observatory, has published in a paper on the subject, entitled "The Photochronograph and its Application to Star Transits," a description of the form of instrument devised and adopted by him in determining the places in right ascension of a zone of the bright stars. My own contribution to this subject consisted in a series of experiments at the Harvard College Observatory in the summer of 1889, by which the star was successfully referred to the collimation axis of the telescope, using photography alone, the first complete transit being thus obtained. Since that time I have been interested in reducing the method to a practical form, and upon introducing the subject to Mr. G. Saegmuller of Washington, and Rev. Fr. Hagen, Director of the Georgetown College Observatory, was encouraged by substantial coöperation on their part in the construction and use of the pre-

* Read before the Washington Philosophical Society.

liminary forms of apparatus. Without going further into any detailed description of the apparatus than can be found in the papers above mentioned, it is my purpose to give a summary of the present status of the process as an art, and to discuss briefly the main points that seem to have been brought out conspicuously in the course of experiments.

There are two different modes of making the record of the star transit as referred to the instants of time indicated by the clock, and one method of inscribing the transit upon the reticule of the telescope. In order to clear the ground for the discussion involved in a comparison of the two ways of operating the plate, it may be said that the reference of the recorded instants of time to the collimation axis of the telescope is accomplished by illuminating the field of the telescope for two or three seconds, by means of a bright light held in front of the object glass. The action of this light is to fog down the whole exposed area of the plate very uniformly, with the exception of the spaces lying behind the reticle threads, which appear upon development to have definite edges, suitable for the setting of a micrometer thread. These boundary lines, being shadows cast by rectilinear rays of light, are much sharper than the trails produced by the moving image of the star. For simplicity and accuracy nothing can be desired in this regard, and my plates produced in Cambridge by this process are excellent. At first it was supposed that rather thick threads would be needed to cast this shadow, but I soon found by trial, as was done in exposing some plates on the large meridian circle of the Observatory and also on the small Russian Transit, that the ordinary glass ruled reticles were suitable, thus disposing of the necessity of making special reticles and also of the danger of breaking the threads, as is likely to happen during operations in the dark. The photographic plate is, of course, to be placed as near the plane of the reticle as is convenient, but experiment showed that a considerable range is permissible without introducing any blurring of the edges, which would be caused by the light coming from the sides of the object-glass if the plate was located at any great distance from the apex of the cone of rays.

The two methods already introduced for connecting the transit with the clock are as follows: 1, the alternating motion of the plate, perpendicularly to the trail of the star, through a small distance approximately that of the width of the trail itself, the effect being to cause a double row of dots to be seen upon the developed plate; and 2, the alternate exposure and occultation of

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the star trail by means of a bar moved in obedience to the clock, the result being a series of dots along a single star trail. The former method was devised by Professor E. C. Pickering, and the latter was adapted by Fr. Fargis, having been used for similar purposes during many years in Kew Magnetographs, and in other instruments for physical measurements.

The occulting bar method is fully described and illustrated in the Monograph of the Georgetown Observatory already referred to, but in order to bring into comparison with it the action of the alternating plate, I take the liberty of introducing an illustration with a short description of the way in which it was made. Each of these methods has such obvious advantages that it seems good to present them together in order that other workers in this field may have the benefit of our experience.

The illustration is an enlargement from a plate on which the diameter of the field of view is about 50*m.m.* The original plate was exposed in the small equatorial telescope, with uncorrected or visual lens, of aperture 6¼ inches and focal length 83¾ inches.

As the work was experimental all the arrangements were of the simplest kind, and this accounts for the crudities seen on the plate. The reticle was of silk thread drawn through holes in a small ring, which was secured to the end of the tail-piece by a bed of wax. The plate rested in a small paper holder, of utility chiefly in passing from the dome to the laboratory, and this was moved on a frame between two sets of abutting screws, through the narrow range exhibited in the photograph. The motion was communicated to the plate by the observer making and breaking the circuit in the current passing through the magnet which controlled the armature and frame, counting the beats of a chronometer, the armature being rigidly joined to the frame. There are endless mechanical combinations for this purpose, the only requisite in them all being that the plate move parallel to itself through the distance occupied by the breadth of the trail, and that it have no motion sidewise, a combination easy to secure by fine pivots or by a thin flexible spring. It should be stated here with emphasis that the only prime necessity is that this operation be *constant in its action*, inasmuch as the corresponding interval of time goes into the determination of the clock error and then comes out again upon applying the correction. In short, the main advantage of this system is to reduce the transit to certain constant mechanical errors, instead of to the fluctuating errors involved in the personal equation.

The star shown is α Aquilæ, Altair, 1.2 mag., selected for its

advantage in reproduction for THE JOURNAL. There are several trails set at different altitudes: 1, an unbroken trail; 2, a trail alternating every second for an interval of two minutes; 3, a broken trail showing ten second intervals unbroken, or broken into seconds; and 4, a broken trail showing ten and twenty second intervals.

I will state at this place that from my knowledge of the ability of this work to record a star transit relatively to any chosen thread in the telescope, that the *error need not exceed one hundredth of a second of time*, so far as the transit is concerned, and that it is *wholly free from personal equation*. Of course the final resulting place of the star as reduced to any epoch, will contain the errors arising from the performance of the clock and from the determination of the level, azimuth and collimation of the instrument. We are not now concerned with the variations arising from these sources, but we are aiming to show that the position of the star relatively to the reticle can be accurately determined. A mere inspection of the situation suggests that the position of the star in declination admits of an equal degree of precision in discussion. When the fluctuating motion of the star is considered, caused by the movements of the atmosphere, whereby it is literally tossed about, also the fact that in any transit observed in the usual manner the setting is made upon some momentary position, the advantage of such a permanent record across the whole field must add greatly to our resources in dealing with the subject.

In the original plate the motion was controlled by the observer's hand, but a commutator can be constructed with several combinations of second intervals that will operate automatically from the standard clock. Mr. Gerrish has such an one at the Harvard College Observatory which works excellently. In principle it consists of a finger resting on the surface of a copper disc or set of discs, which jump forward one notch by the clock each second, the disc having insulated spaces of greater or less length, so that the finger makes or breaks the circuit for the interval that it rests upon a copper or a rubber space respectively. The action is steady and follows the clock with precision. It will be seen that the use of such an arrangement is necessary, because otherwise the work will be confined to an equatorial belt, if the intervals are limited to the second breaks of the standard clock.

The advantages possessed by the use of the alternating plate can be summarized as follows: 1. It secures the full value of the star trail as an actinic effect, its brightness not being obscured during the transit. Inasmuch as the photographic process is

ineffectual below the stars of 4° magnitude near the equator, in small telescopes, this is important. If stars are taken nearer the poles by means of the commutator, the fainter stars may be called into use, as their slower motion will give the requisite trail, the time observation being compensated in the ratio of the secant of the declination. 2. The action of the clock marks sharply the instant it breaks, one interval being ended and the other begun. The photographic spreading of the light is in opposite directions, but unobstructed, so that the instant is not transferred along the line by any changes in the battery or the auxilary apparatus. Thus the breaks follow the clock absolutely. If the breaks were made upon a single line, one of two results must happen, as in the case of the occulting bar; either the interval of exposure must be very short with reference to the occulted interval, on account of the spreading of the photographic image in the film, as for example, one-tenth to nine-tenths of a second; or else the trail ends will blurr into each other so as to become useless. If an exposure is a small fraction of a second, the number of stars whose brightness is available will be considerably diminished near the equator, and also it will be impossible to extend the method towards the poles, because the angular motion of the star shortens up so much that tenth-second exposures unite with one another. This is a serious disadvantage inasmuch as the bright stars of this region are omitted from the determination of instrumental errors, and also from the final and resulting catalogue.

The advantages of the occulting bar have been carefully enumerated in the Georgetown paper. They are: 1, the extreme simplicity and the lightness of the apparatus, these qualities obviously being at a maximum; 2, the fixed position of the photographic plate during the making of it.

There are certain disadvantages inhering in each system, some of which are common to both and others which are peculiar to one or the other method: 1, the objection arising from the so-called photographic parallax, or blurring of the edge of the reticle lines by the action of the light in passing from the reticle to the plate, has been stated as belonging to the alternating plate, but it is common to both, if it exists at all, because this distance is so small that the angular aperture of the telescope transferred from the photographic focus to the plate represents an infinitesimal linear distance upon it, and also being symmetrically distributed does not shift the center of the image of the thread; 2, the partial obliteration of the trail, said to be produced in the illum-

ination of the object-glass unless covered by the occulting bar, was never seen to exist in the work at Cambridge, but it was always supposed that the general face of the plate and the star trail itself both advanced a little in density during the operation, so that the original contrast in color, would persist. In short I never found that a long illumination, up to nearly the point of blacking the plate, as compared with a very brief one, tended to obscure the star trail. Certainly in practice there is no danger of losing a trail by this fact. On the other hand it would seem to be advantageous to retain the impression of the horizontal threads, and it will be necessary to do so if the work is to include, as it ought, the determination of the star place in declination as well as in right ascension.

The objection arising from changes in the action of the battery, the springs and the moving parts of the apparatus, or the variable component of the force of gravity, would at first sight seem to be against the alternating plate on account of its weight, and in favor of the occulting bar on account of its lightness. But it is quite otherwise. The weight of the moving part consists of a bit of thin glass one inch square, and of a light metallic frame to hold it, which rocks on pivots or a piece of spring, since by using a ruby light in the observing room the plate box can be abandoned. My first plate holder consisted of a folded piece of black paper; we afterwards tried metalic holders in Washington, but I should advise the use of none. With a much heavier plate-holder at Cambridge, and using two Daniell's cells, I never found any trouble arising from this cause.

By recalling the action of the break on a chronograph the point I have to make will be evident. The *beginning* of the break is always sharp and constant, responding to the clock precisely; the *length* of the break varies, depending upon the battery, the spring and friction. The alternating plate uses the beginning of the motion only for its point of reference; the occulting bar uses the dot produced by the total break, and since the micrometer thread is set into the middle of this dot, its position relatively to the beginning of the clock beat is clearly a function of the motion involved. My opinion is that very little practical value adheres in this objection as against either form of apparatus, but the theoretical objection is not against the alternating plate.

The question will finally be settled by a comparison of the validity of two main difficulties that have already been mentioned.

The first point raised by one who looks into the apparatus used in the alternating method is that *the plate moves.* There is one

reply that covers the ground. The plate moves, but it moves in a *constant fashion*, and whatever that motion may have been, the reticle is thrown down upon it accurately, so that the micrometer measures take up all the movement that may exist. It will have to be shown that the mechanical operation of the plate, through the space of three-tenths of a millimeter, is a *variable* action before the objection becomes valid. I have seen no reason to suspect it in the apparatus that I employed.

It is this objection that will have to be offset against the tenth of a second exposures used in the occulting bar process. Increasing the exposures to nine-tenths of a second, as can be done, will blur the series of dots into one line so that the setting of a micrometer thread cannot be made upon the clock intervals. To vary the exposure from one-tenth to two, three or four-tenths of a second, will shift the time of a transit along by half the variation of the interval, and this cannot be measured accurately. To change in any other manner involves the use of a commutator as above described. Not to make these variations is to limit the work to the equatorial belt of stars, at the sacrifice of the polar regions for all purposes. At present I see no way of escape from using the alternating plate and commutator, or limiting the work so far as to fail in its complete development.

We have only space to enumerate, but not to discuss, some definite advantages of the photographic transits, by whatever methods they are taken:

1. The general accuracy of the transit itself is well known to all who have operated with the method, the average error being about one-hundredth of a second.

2. The freedom from a variable personal eqation is unquestioned.

3. The permanence of the record of the transit, as compared with fleeting vision of the star that has passed over the field, not only enables a complete discussion of the event, but a comparison of the transits of the same star at widely different epochs.

4. The superior accuracy of each transit involves a much more rapid approximation to the true result, than by the method of taking the mean of many inferior observations. As the precision increases the necessary cost of observation and computation will diminish.

5. It is obvious that the application of this method to the determination of Longitudes has decided advantages. The clock at one station will beat the breaks of the chronograph at each station and also the star transit, all at the same time. By alter-

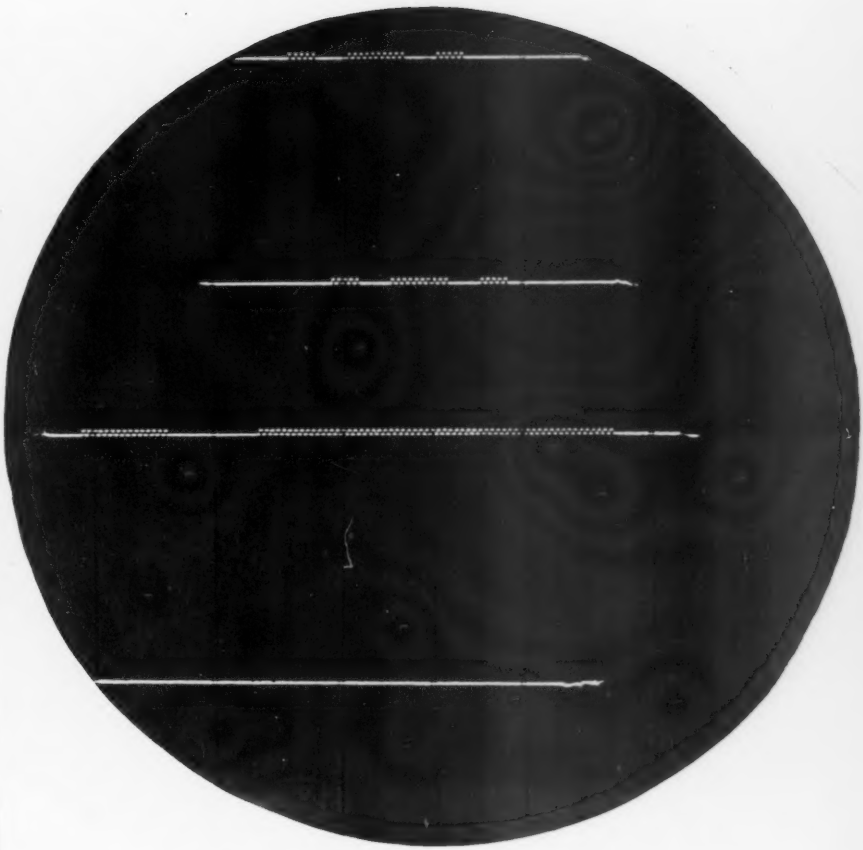

PLATE Accompanying Professor Bigelow's Paper on the Photographic Method of Determining Stellar Places by Transits Freed from the Error of Personal Equation.

nating the clocks of two stations in this way a most interesting result should be obtained.

6. In determining the variablity of latitudes it will be only necessary to take the star trail of a zenith star, the time being marked by the clock beats, referring the same to a series of horizontal reticle threads. A comparison of a set of such plates taken throughout a year should give a strong hold upon the problem. The principal advantage is that the variations of the atmosphere, and the tossing about of the light of the star, is recorded accurately, the whole case being completely taken down at each exposure.

7. Finally a catalogue of bright stars in both right ascension and declination, for use in connection with the photographic charts of the heavens will be very important. The comparability of the ways in which they are both produced, will make their fitness for each other recognized at once.

8. There are many meridian circles of the older patterns which might readily be turned to such work as that suggested above, since their object glasses will give satisfactory results, as has already been demonstrated. The prime requisite is practical skill in producing the results, the first cost in money being insignificant.

This subject is, therefore, cordially commended to the attention of such as have time to bestow upon these most promising astronomical investigations.

WASHINGTON, Nov. 20, 1891.

ON THE ABSORPTION OF HEAT IN THE SOLAR ATMOSPHERE.*

W. E. WILSON, M. R. I. A., F. R. A. S.

The author endeavors to determine with accuracy the ratio of the heat received from the limb and the center of the solar disc, and thus by taking yearly observations through a sun-spot cycle, to find out if the solar atmosphere varies in depth.

The apparatus consists of a heliostat which throws a small pencil of sunlight into a dark room. It is received on a 4-inch concave silver-on-glass mirror of about 10 feet focus. A small convex mirror is placed inside the focus of the concave mirror, and thus forms an image of the sun of 80 centimètres in diameter. This image is allowed to fall on a radio-micrometer of Pro-

* Communicated by the Author.

fessor C. E. Boys. The tube of the instrument is stopped down to nearly 1 mm. in diameter, so that only about $\frac{1}{500000}$ part of the solar image is at any moment giving its heat to the instrument.

A slice of lime-light is allowed to fall on the mirror of the radio-micrometer, and is reflected from it on to a horizontal slit in the side of a box which contains a photo-plate. This plate during an observation is allowed to fall with a uniform rate by a piece of clock-work. Any motion of the mirror of the radio-micrometer thus records itself on the plate in a curved line.

The clock of the heliostat is stopped and the image of the sun is allowed to transit across the mouth of the radio-micrometer, and the curve giving the values of the heat received from the solar disc is recorded on the photo plate.

A seconds pendulum swings across the track of the limelight, so that the photo curve is notched into seconds of time, and a means is thus given of localizing the position of the instrument on the solar disc.

THE ULTRA-VIOLET SPECTRUM OF THE SOLAR PROMINENCES.*

GEORGE E. HALE.

In various papers published during the past year I have called attention to some of the advances in our knowledge of the Solar Prominences which might be expected to follow the application of photographic methods to a study of their forms and spectra. The August number of the *American Journal of Science* contains reproductions of some photographs obtained in the course of my investigations on this subject at the Kenwood Astro-Physical Observatory. I am indebted to Professor Lockyer for the use of a measuring machine during a recent visit to London, and I am now able to give my determinations of wave-length for the new prominence lines, and some conclusions to be drawn from them. But perhaps it will first be well to consider for a moment the apparatus and methods at present employed in the work.

To the eye-end of the 12.2-inch equatorial refractor of the Kenwood Observatory a large solar spectroscope is rigidly attached by three steel tubes, and as the spectroscope extends about five feet beyond the focus of the telescope, the declination axis is

* Read at the Cardiff meeting of the British Association for the Advancement of Science, August, 1891.

placed at the center of the combined lengths of the two instruments, in order to reduce the amount of counter-balance required at the object-glass end. The result is very satisfactory, and there can certainly be little fear of flexure in the combination. The whole spectroscope may be rotated by a rack and pinion, so as to make the slit tangential or radial at any point on the Sun's limb. The object-glasses of the collimator and observing telescope have 3¼ inches clear aperture, and 42½ inches focal length. The 4-inch Rowland grating is ruled with 14,438 lines to the inch, and as the telescopes make with each other a constant angle of 25°, different orders of spectra are brought into the field of view by rotating the grating. A diagonal eye-piece at the end of the observing telescope allows the spectrum to be observed after the photographic plate is in position.

In photographing the spectrum of a prominence the following is the ordinary process. Let us suppose that it is desired to use a radial slit, in the H and K region of the spectrum. The C line in the second order is brought into the field, and while observing this line the spectroscope is rotated until the slit is radial at some point on the limb where a prominence is seen. The driving-clock is then started, and the telescope clamped, so that the sun's image is kept as nearly as possible stationary on the slit plate. A small strip of metal, pushed in just behind the slit, excludes the direct solar light, except from a small region near the limb. The whole collimator is next moved by a screw until the slit is brought to the proper focus of the equatorial for K, and the collimator and observing telescope are set at the focus for the same line, the positions being taken from a table of foci, determined by experiment, for the principal lines in the spectrum. After placing the sensitive plate in position, the grating is rotated until the K line in the fourth order is in the middle of the field, the slit is covered, the slide drawn, and the proper exposure given. The exposure of course depends upon the aperture and focal length of the equatorial, the width of the slit, the brilliancy of the grating, the sensitiveness of the plate, etc., but with the ordinary dry plate of sensitometer No. 23 furnished by the Seed Company, and a slit about 0.001 inches wide, I usually find that an exposure of from 20 to 30 seconds gives the best result.

For the first time without an eclipse the prominence spectrum was thus photographed early in April of the present year. The only bright lines then obtained were found to fall nearly at the centers of the dark bands H and K of the solar spectrum, but these were remarkably strong, seeming to fully equal C in inten-

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sity, and were present in every prominence photographed. Work was continued on the violet and ultra-violet for some weeks, but with the exception of some lines which had all the appearance of ghosts of the brilliant H and K reversals, no new lines were discovered until June 23, when an exceptionally bright prominence was found. This gave four lines in the ultra-violet, and the least refrangible of these was found to be double. A line slightly less refrangible than H, nearly but not quite at the position where the first ghost would be expected to fall, was much stronger than any of the other ghosts, and it seemed very possible that it was an independent line. This prominence remained visible for several days, and a number of photographs of its spectrum were made with both radial and tangential slit.

In reducing the wave-lengths of these lines it might be considered easy to obtain values for a given line agreeing closely in the hundredths place of tenth-meters, but two causes have combined to lessen the accuracy of determinations. The H and K reversals almost invariably show some indications of motion of the prominences in the line of sight, and the consequent distortion renders somewhat difficult the proper setting of the spider line of the measuring machine. Again, the plate-holder used was made for another purpose, which required that the plane of the plate should be at right angles to the axis of the observing telescope. As the object-glass of the telescope is corrected for the visual region, it is evident that near K there must be a slight change in focus from one side of the plate to the other, and a small error is thus introduced. It will be seen, however, that the measures are sufficiently accurate to allow very little doubt as to the identity of most of the lines. The fact that the solar spectrum, due to the diffuse light of the atmosphere, is photographed simultaneously with the prominence spectrum, is of great advantage in determining the position of the prominence lines, though it has a corresponding disadvantage in concealing very faint lines, which would otherwise be brought out. The wave-lengths of certain standard lines in the solar spectrum have been taken from the list published by Professor Rowland,* and it has thus been easy to find the wave-lengths of the prominence lines by simple interpolation. The value of the micrometer screw has been determined for several regions on every plate by measuring the positions of properly distributed standard lines, the number of separate settings of the spider line in each case ranging from five to fifteen, depending upon the character of the line measured. In the following table

* "Amer. Jour. Sci.," 1887, p. 182.

the first column contains the wave-lengths of the ultra-violet prominence lines; the second the positions assigned by Ames to lines in the hydrogen stellar series; and the third, the wave-lengths of the calcium lines at H and K, which Professor Rowland has been kind enough to furnish in advance of publication. I am informed that they are provisional only, but may be relied on to within 1 or 2 in the last place of decimals. In the case of hydrogen, Ames considers that the error in any wave-length cannot amount to more than 0.05 of a unit,* and my own values for the prominence lines must possess about an equal degree of accuracy. In the fourth and fifth columns I have added Cornu's measures of the hydrogen lines,† and Dr. Huggins' wave-lengths of lines in the hydrogen stellar series,‡ both reduced to the scale of Rowland's map.

Prominences. Hale	Hydrogen. Ames.	Calcium. Rowland.	Hydrogen. Cornu.	First Type Stars. Huggins.
3968.56	...	3968.61 (H)	...	...
3933.86	...	3933.80 (K)	...	...
3888.73	...	...	...	...
3970.11(?)	3970.25	...	3969.6	3969.6
3889.14	3889.15	...	3888.5	3888.2
3835.54	3835.6	...	3835.1	3834.6
3798.1	3798.0	...	3797.5	3795.6
3770.8	3770.7	...	3770.0	3768.1
...	3750.15	...	3749.9	3746.1
...	3734.15	...	3734.2	3730.6
...	3721.8	...	3721.1	3717.9
...	3711.9	...	3711.1	3707.9
...	...	...	...	3699.4

Let us first consider the prominence lines which lie near the centres of the broad dark shades at H and K. In his observations of the chromosphere and prominence spectrum at Mount Sherman, in 1872, Professor Young succeeded in seeing these reversals in a number of cases, but the character of the bright lines could not be made out, and it was considered probable that the broad dark bands were included in the reversal, only the brighter central portions, however, being strong enough to affect the eye. We now find, on the contrary, that the substance producing the bright prominence lines may possibly be entirely distinct from that causing the broad bands in the solar spectrum, for though the lines certainly do lie near the centres of the bands, they are narrow and sharp, and it is easily conceivable that their position may be simply the result of chance, though perhaps probability would point the other way. We are hardly in a

* "Phil. Mag.," July, 1890, p. 49.
† "Journal de Physique," [10] V. (1886)
‡ "Phil. Trans." Part II., 1880, p. 669.

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position to discuss the cause of the unique appearance of the dark H and K bands, but it may be that we may learn something in this connection from Dr. Huggins' important investigations of stellar spectra. It will be remembered by everyone that in his memoir "On the Photographic Spectra of Stars" communicated to the Royal Society in 1880, Dr. Huggins arranged the stars observed in a series, in which the principal criterion of position was the character of the K line. In Arcturus, for instance, this line is broader and more diffuse than in the sun itself, while in Sirius it has narrowed down to a fine, sharp line. Other stars give intermediate breadths, and in some instances it has entirely disappeared. In the case of H the question is complicated by the fact that hydrogen and calcium possess lines which form a close double at this point, so it is best to consider only K. From the variations of this line it will be seen, apart from the interesting subject of stellar evolution so evidently suggested, that the narrow dark line at the centre is very possibly produced by the same substance which, vibrating under different conditions, causes by its absorption the broad dark band.

As the central dark line is known with a high degree of certainty to be due to calcium, it becomes likely that the band is due to the same substance, and as the central dark line of H is also a calcium line, it might perhaps be safe to attribute the H band to the same metal, though in neither case is it well to be too positive in the assertion, for it is somewhat peculiar that the bands and lines appear together in the solar spectrum. If the same substance produces both, and each requires different conditions, possibly of temperature or pressure, for its production, these conditions must presumably exist at different elevations above the photosphere.

The question now arises whether the bright lines in the prominence spectrum agree in position with the dark lines at the centres of the H and K bands. Only one or two of my prominence spectra happened to be given the proper exposure to bring out both the bright and dark lines, but in these the coincidence is fairly satisfactory. I have not as yet, however, been able to obtain the wave-lengths of the dark lines in hundredths of a tenth-metre, but Professor Rowland's determinations of wave-lengths for the corresponding calcium lines will answer nearly as well. These have been given in the third column of the table of wave-lengths. It will be seen that in the case of H the prominence line is 0.05 tenth-metres more refrangible, while at K the prominence line is 0.06 tenth-metres less refrangible. Professor Rowland

considers his values correct within 1 or 2 hundredths tenth-metres, while the probable errors in the position of the prominence lines, deduced on the assumption of equal weights for the wave-lengths given by each of six plates, are 0.021 and 0.036 tenth-metres for H and K respectively. On the whole, then, there can be little doubt that these prominence lines are due to calcium, and are therefore probably true reversals of the central dark lines of the H and K bands.

It will be of interest next to consider briefly the character of these two prominence lines. In all cases they are quite narrow and sharp, except when motion in the line of sight has produced broadening or distortion. In seven photographs made with a radial slit both lines gradually become narrower as the distance from the limb increases, and have a pointed appearance. This might be due to an actual decrease in the width of the lines, but, as there is usually a certain increase of intensity toward the limb, the effect may be purely photographic. In several plates, however, there is so little change of intensity that the widening can hardly be due to this cause. The arrow-head appearance, so frequently seen with the C and F lines, is often shown when the slit is radial. A rather curious appearance has been found on three plates made with radial slit, and in the two which best show the effect there is a very sudden decrease of intensity in the upper part of the lines. Instead of becoming narrower toward the top, the lines seem to expand symmetrically on either side, and the edges become hazy and indistinct. As in the case of the pointed lines, there is also an expansion toward the limb, but here the edges are clearly defined. The arrow-head appearance is shown in two of these plates. With a tangential slit two plates show the lines expanded at the ends, and in one plate they are pointed. Though in most cases the forms of H and K are very similar, there is a single instance where K is shown sharply double in the fainter portions at each end of the line, and at one end the components seem to diverge slightly. That this is not the result of poor focusing is attested by the sharpness of the lines in the background of solar spectrum; at the same time the appearance is hardly that of an ordinary reversal. One further peculiarity will show that it is safest, for the present at least, not to draw any conclusions from such appearances as have been noted. In a certain position of the mirror of the measuring machine the illumination was such that the edges of the radial black lines appeared bright, while the Fraunhofer lines of the solar spectrum were also bright, as with ordinary illumination.

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One of the negatives, in which H and K were broader and fainter at the top, brought out the effect particularly well. The central dark line extended two-thirds of the distance to the top of the prominence, and in the upper part it was excessively narrow and delicate. Lower down it gradually widened, until at a point very near the limb the widening became much more rapid, and at the limb itself the line was nearly as wide as when seen under ordinary conditions.

A paragraph from Dr. Schuster's report on the results obtained with the spectroscopic cameras at the total eclipse of August 29, 1886, seems to refer to a somewhat similar appearance. Speaking of the photographs of the coronal spectrum, Dr. Schuster remarks*: "A bright line shows black on the negative, and is bounded on both sides by an apparently lighter background. This is a well-known contrast effect. The H and K lines, for instance, seem to be surrounded by a lighter band, which follows the contour not only of the lines, but also of the wing by the side of the prominence. If, now, a Fraunhofer line happens to be by the side of a bright line, the contrast is strengthened, and both the bright and the dark lines appear more distinctly than they otherwise would. This is the only simple way in which I can explain some of the appearances of the photographs." The first part of the quotation is all that concerns us at present, for in the negative which I have mentioned as showing this peculiarity particularly well, the Fraunhofer lines are hardly visible above the limb, and none appear within the dark bands at H and K. As Dr. Schuster does not speak of the illumination, I assume that the appearance was generally seen, and this constitutes another point of difference. A penumbra formed by light reflected from the back of the plate would probably extend but little higher than the central line, but in the future plates backed with a dyed collodion film will be employed to obviate any effects of this kind. No entirely satisfactory explanation of the peculiar appearance of these lines has as yet suggested itself.

But on another point there is little room for doubt. The bright H and K lines certainly extend to a very considerable elevation above the sun's limb, and it is extremely probable that calcium is carried to the very top of the highest prominences. With the improved apparatus to be used in a continuation of this research, I hope to be able to ascertain the relative heights of various lines in the prominence spectrum. For in-

* "Phil. Trans." Vol. 180 (1889), (A.) p. 329.

stance, while a photograph is being made of H and K, the height of C in the same prominence can be measured with a micrometer. The comparative observations and photographs made up to the present time suggest the belief that calcium attains the highest elevations reached by hydrogen, and the remarkable brilliancy of H and K at the eclipse of 1882 attest the importance of calcium in the prominences. Dr. Schuster is of the opinion that the coronal spectrum contains calcium injected by the prominences, and this may only very gradually descend again to the level of the photosphere*. This supposition seems a very plausible one, and if it be at the same time considered probable that the H and K bands and their central lines are produced by the same substance, the possibility is suggested that the broad dark shades may be caused by the absorption of the cooler vapor at a considerable elevation, while the absorption near the photosphere gives rise to the narrow central lines. This view need not necessarily conflict with a belief in a shallow reversing layer, where absorption ordinarily takes place, for the H and K bands are unique in the solar spectrum. It rests, however, on somewhat insecure foundations, and cannot be credited with much weight.

On account of the dark shades at H and K it has proved quite easy to photograph prominence forms with an open slit. With other prominence lines the brilliancy of the background is much increased when the slit is opened, but this is not the case with H and K, and it is often possible to use a slit nearly a quarter of an inch wide. The fourth order spectrum has been employed for this work, and the best results are obtained with an exposure of about one second. It is considered that great advantage will result from a material reduction of this exposure, as the disturbances in our atmosphere have as yet made it impossible to secure the finest details of structure.

It is of interest to note, however, that the first photograph ever taken of the rapid development of a prominence was made in this way by my assistants on July 8, 1891, at $23^h\ 55^m$ Chicago M. T. As at first observed through C, the prominence was low, but very bright, and changing rapidly. A great tongue moved rapidly out to an elevation of about 80,000 miles, and at this time the extension was photographed through H and K. In fifteen minutes the prominence had returned to its original form. A reproduction of the photograph is given in the August number of the "American Journal of Science," and though much has been lost in the printing process, some idea of the actual appearance of the prom-

* "Phil. Trans." Vol. 180 (1889), (A.) p. 328.

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inence may be gained.* A new apparatus for photographing the prominences is now being constructed as the outcome of my investigations on this subject, and this is expected to do away with many of the difficulties previously encountered. It will consist of two slits, moved in opposite directions across the ends of the stationary collimator and observing telescope by means of a peculiar form of clepsydra. The sun's image and photographic plate will be stationary, and the apparatus is thus to be constructed on the principle of the second method devised by myself in 1889, but so altered as to avoid the defects of the original scheme.†

Decision must be reserved for the present as to the line at λ 3970.11. The wave-length has been determined from four plates, but as the line is not far from where a ghost of H should fall, I cannot be certain that it belongs to the prominence spectrum. At the same time it is very much brighter than any other of the seven ghosts of H and K, and its position with respect to H is not symmetrical with that of the first ghost on the opposite side of this line, while in the case of K the ghosts are very regularly spaced. My assistants report that they were able to *see* H very plainly double in a brilliant metallic prominence observed July 27, and on several occasions Professor Young has made out the same thing. The agreement in wave-length with Ames' hydrogen line at 3970.25 is by no means satisfactory, and more observations and measures are required before a conclusion can be reached.

No one can doubt that the next four prominence lines are members of the well-known hydrogen series, for their agreement in wave-length with the values given by Ames is certainly very striking. Cornu's measures show considerable differences, as do also those of Dr. Huggins, but the small dispersion employed by the latter in this investigation must be borne in mind. There can be little question that Ames' wave-lengths are very near the truth, for they almost exactly correspond with those calculated by Balmer's formula. The measures of the prominence lines also serve to confirm them.

The remaining prominence line at λ 3888.73 has not been accounted for. It forms a close double with the hydrogen line at at λ 3889.14, and with it attains as great elevations above the limb as those reached by H and K. The character of the lines,

* See also Plate III.

† For previous papers on prominence photography see—"Technology Quarterly," Vol. III., No. 4, 1890. "Astronomische Nachrichten," Nos. 3006, 3037 and 3053. "Sidereal Messenger," June, 1891. "Amer. Jour. Sci.," August, 1891.

however, is quite different, for while the hydrogen line is wider, and slightly diffused the line at λ 3888.73 is very narrow and sharp. I have seen no statement that the hydrogen line has shown any signs of duplicity, and, as Mrs. Huggins has had the kindness to examine the corresponding line in some very sharp photographs of stellar spectra with the same result, we have reason to consider an independent origin probable.

The results so far obtained can only be regarded as preliminary, for with the improvements now being carried out in the telescope and spectroscope, and the much greater frequency of metallic eruptions as the maximum sun-spot period is approached, it is certainly to be hoped that many more lines will be photographed. The ultra-violet spectra of sun-spots have also been worked upon with some indications of success, and there will evidently be no lack of opportunity in the new and interesting fields thus opened to investigation.

LONDON, August 13, 1891.

NOTE ON THE CHROMOSPHERE SPECTRUM.*

PROFESSOR C. A. YOUNG.

With the new spectroscope of the Halsted Observatory, which has a 5-inch Rowland grating of 20,000 lines to the inch, I have repeatedly observed of late that the bright chromosphere line, Angström 6676.9 (No. 2 in my catalogue of the chromosphere lines), is not coincident with the corresponding dark line of the solar spectrum, but is *less refrangible* by about one-third of a unit of Rowland's scale. This chromosphere line, therefore, can no longer be ascribed to iron, but must be due to some other substance as yet undetermined.

I think there can be no doubt as to the non-coincidence. The interval between the bright and dark lines varies to some extent with circumstances, being usually less in the chromosphere spectrum on the sun's eastern limb than on the western, and it is often affected by motions in the line of sight, but nine times out of ten the want of coincidence is perfectly obvious.

I may add that I have also obtained a considerable number of photographs of the ultra-violet spectrum of the chromosphere with the new instrument, and get complete confirmation of almost all Mr. Hale's results. I find not only the constant reversal of the H and K lines, but I have obtained, so far, five of the ultra-

* Nature, Nov. 12, 1891.

violet series of hydrogen lines; the first of them being the well-known "companion" of H (first visually observed by myself in 1880), and the other four in their regular succession above it.

The only point in which my plates fail to confirm Mr. Hale's is that I have not yet succeeded in catching the duplicity of the hydrogen α (3889). Several of his plates show at this point two lines near together; none of mine do so, and I conclude that the companion line makes its appearance only rarely. I first observed this line visually in 1883 (*American Journal of Science*, November 1883), and it has since been often seen by my assistant, Mr. Reed, as well as by myself.

Of course the opinion is no longer tenable that H and K can be due to hydrogen, since the measures clearly show that the companion to H belongs to the hydrogen series. But I am still sceptical whether they are due to calcium, at least in its terrestrial condition.

PRINCETON, N. J., Oct. 20, 1891.

NEW RESEARCHES ON THE SOLAR ATMOSPHERE.*

M. H. DESLANDRSE, PARIS OBSERVATORY.

I have been commissioned by Admiral Mouchez to inaugurate a new department at the Paris Observatory for spectroscopic investigations, which form the most important branch of physical astronomy, and I have directed my efforts in part toward the study of the Sun. I have the honor to present to the Academy the first results obtained in this new direction.

Method—Apparatus. I have studied the atmosphere of the Sun in a part of its radiation not yet explored. Every day in many observatories, the chromosphere and the prominences are observed by the method of M. Janssen, but with the eye only, and in the brightest part of the visible spectrum, the red, the yellow and the green. Now I have applied the same method in another region of the spectrum, which is barely visible, or even invisible, but easy to photograph, and which includes the blue, the violet, and a part of the invisible ultra-violet, as far as λ 380.

The instruments employed are the following: 1st. The siderostat of Foucault, which, in the estimation of its illustrious designer, was especially suited to solar work; 2d. An old 12-inch objective by Lerebours, which I have corrected for the chemical

* "Comptes Rendus de l'Académie des Science," 17 August, 1891.

rays by separating the two lenses; 3d. A photographic spectroscope with 1, 2 or 3 prisms of light flint.

Results. In spite of the small dispersion used I have obtained the permanent lines of the chromosphere in the blue and violet, observed with the eye by Professor Young from the summit of a high mountain, *i. e.*, the G′ and *h* lines of hydrogen, and H and K of calcium. But by photography the intensities of these lines present some important differences. The H and K lines, which are at the limit of visibility, are recorded by Professor Young as thirty times less intense than the line G′ of hydrogen. Now the numerous photographs made on the entire limb of the sun during the months of May, June and July, 1891, show clearly the lines of calcium much longer and more intense than the lines of hydrogen; they are often strong when the hydrogen lines are very faint.

Besides this I have also obtained the permanent faint line a little less refrangible than H, and recorded in Professor Young's list with the remark, "element unknown," but I have identified this line as one of hydrogen, by direct comparison with a Geissler tube.

Finally, in the invisible ultra-violet region, I have obtained two new permanent lines which correspond with the first two lines of hydrogen in Dr. Huggins' stellar series.

But the most important result is the marked predominance of the lines attributed to calcium. The corresponding vapors rise higher than do those of hydrogen, a fact which overthrows the accepted ideas on the composition of the solar atmosphere. This result is less astonishing when it is considered that the H and K lines are the broadest in the ordinary solar spectrum, and should consequently be very strong in the absorbing layer. It is moreover, in accordance with the great extension of these same lines shown in photographs of the corona spectrum made during the eclipses of 1882, 1883 and 1886 by Messrs. Abney and Schuster.*

Another property of these bright lines of calcium, important from a practical point of view, is the possibility of obtaining them with a very low dispersion. The great width of the black background on which they are projected gives them this advantage, and even partially explains their great extension. With the hydrogen lines, on the contrary, the discovery of the proninences,

* On a high mountain, and with an apparatus of low dispersion, the bright lines of calcium will be still longer, and thus the corona, properly so called, will be obtained. The distinction between the corona, the chromosphere, and the prominences is entirely relative, and depends upon the region of the spectrum considered, and the conditions of the experiment.

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as is well known, was delayed for two years by the insufficient dispersion of the apparatus employed.

I have the honor to present to the Academy several photographs of these calcium reversals. One of these shows a prominence at 311°, June 18, $2^h\ 55^m$ M. T., moving with a gyratory motion. One extremity approaches the earth, in fact, with a velocity which, determined from the photograph according to the principle of M. Fizeau, is about 62 kilometres, the other extremity with the smaller velocity of 25 kilometres. The direction of the rotation (a point worth noting) is that of the Sun's rotation. The laws of storms in our own atmosphere apply also to the atmosphere of the sun.

Photographic Record of Form and Velocity.—These photographs require a maximum exposure of two seconds. They can serve for a regular and rapid study of the movements at the surface of the sun, movements which, according to certain ideas now in vogue, are supposed to have an influence on the terrestrial atmosphere. The forms of prominences may also be photographed.

Mr. Hale, who has long been engaged in investigating this last question, has proposed several very ingenious methods for photographing prominences with a narrow slit; but these methods apply only to single prominences, and not to the entire circumference of the sun; besides, they do not give the velocities. I have devised an entirely different arrangement, which may be described as follows:

The spectroscope, which may be of any form, turns continuously around an axis passing through the center of the sun's image, and prolonging the optical axis of the objective. The middle of the slit is on the limb of the sun, all points of which it meets successively by the rotation of the apparatus. Before the photographic plate is placed a fixed slit, which corresponds with the K line of calcium. Moreover, the plate is movable, in such a way that a displacement of the plate corresponds to an equal displacement of the middle of the slit. This result is secured by simple gearing. If then the spectroscope rotates steadily with a suitable velocity, a band equal in length to the circumference of the sun is obtained on the plate, which shows all the prominences with their exact forms. But the velocity of the prominences is not given by this process. It is also necessary to give to the apparatus a series of rapid rotations, separated by periods of two seconds, in such a way as to have on the plate, for example, 200 equidistant sections of the chromosphere on the whole circumfer-

ence of the sun. Each section requiring about three seconds, the whole can be made in ten minutes. If, moreover, the plate is replaced by a piece of sensitive paper rolled on a cylinder, and the movement of the spectroscope made automatic, a simple apparatus will be obtained which will register continuously the form and velocity of the incandescent masses at the surface of the sun.

ON THE ENORMOUS VELOCITY OF A SOLAR PROMINENCE, OBSERVED JUNE 17, 1891.*

JULIUS FENYI, DIRECTOR OF THE HAYNALD OBSERVATORY, KALOCSA, HUNGARY.

On June 17, at $5^h\ 30^m$, Paris mean time, a group of spots in course of development, was seen at 21° latitude, and, according to our calculations, it would pass around the western limb of the sun at 282° from the celestial pole. The phenomena observed in a group of prominences at the same place form the subject of this communication.

An elevation 18″ high and of a dazzling brilliancy, extending from 278° 32′ to 281° from the celestial pole, was with the flame at 282° 42′, the seat of an excessively violent eruption.†

After $5^h\ 42^m$, P. M., Kalocsa mean time, or $4^h\ 36^m$, Paris mean time, the detached parts of the group in question reached the considerable elevation of 109″. As yet the whole complex mass revealed neither motion in the line of sight nor motion of ascent, except the point of the chromosphere at 282° 42′, where the light spread itself outside the slit toward the red.

The violence of the erpution was shown not only by the great brightness of the red line 6677, but also by the fact that the lower parts of the prominence were visible in this metallic line up to the height of 13″; their brilliancy was equal to that of ordinary prominences in the C line.

After 6^h, Kalocsa mean time, the point at 281° shone with so great a brilliancy, that its reddish light seemed to become white; an enormous displacement of the light of the spectrum toward the blue, at a medium height above the sun's limb, indicated at the same time an approach of the hydrogen in our direction, with a prodigious velocity.

The line, that is to say, the image of the slit, appeared com-

* "Comptes Rendus de l'Académie des Sciences," 17 August, 1891.

† On the same day, and at the same place on the sun, M. Trouvelot observed the "luminous phenomena" published in the Note in the Comptes rendus, V. CXII, p. 1421.

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pletely free from reversal; the entire form was outside the line on the side toward the blue, and was composed of luminous filaments directed along the spectrum and changing in appearance, shining like lightning when I drew the image above the slit.

I measured the extent of the displacement by means of a filar micrometer, and, after having carefully determined the dispersion in this region I obtain the enormous velocity of 797 kilometers per second. New measures were taken: they gave 890 kilometers per second as the maximum velocity.

I commenced at that time to determine the height of this moving mass, causing the prominence to pass over the slit, and observing the transit of both the top and the lower extremity.

The result of seven transits, observed in rapid succession, gives an interesting illustration of the progress of the phenomenon:

Transits.	Height on the Limb. Lower Part.	Summit.	Extent of the Column.	Ascent per sec. of Time.		Velocity toward us per second km.
	″	″	″	″	″	
I.	——	182.7	——			337
				——	16.3	
II.	61.8	199.0	137.2			——
				45.4	18.0	
III.	107.2	217.0	109.8			——
				——	−2.7	
IV.	——	214.3	——			——
				35.6	8.2	
V.	——	222.5	——			——
				——	13.8	
VI.	142.8	236.3	93.5			——
				9.5	20.6	
VII.	152.3	256.9	104.6			449

We thus see that a suspended column, measuring 111″ from top to bottom, rose almost vertically in a single mass and with a prodigious velocity to a height of 256″.9. The velocity with which this same mass advanced toward us was also enormous, for the image remained all the time outside the C line; the image of the slit was entirely dark. The displacement of the top, measured with the micrometer before the first and during the last transit gave for the elevation indicated in the table the enormous velocities of 337 kilometers and 449 kilometers per second. The lower parts showed a still greater deviation than that of the top.

It is impossible for me to follow with exactness the progress of the ascent in all its phases, because we could not determine precisely at what instant each of these phases occurred; but we can at least indicate the mean velocities quite accurately. During each transit I counted only twenty seconds; we can thus safely assume that no one of these observations lasted longer than thirty seconds. As the prominence traversed, during the seven

transits, or in 210 seconds, the distance 79′ 2″,* it must have risen with a mean velocity of at least 485 kilometres per second. Its lower extremity rose more rapidly, if we rely on the first measures taken; however, its progress was evidently retarded, while the top seemed rather to rise with a constantly increasing velocity.

This same mass also possessed a velocity by no means insignificant in the third direction; that of the meridian. According to the data obtained, this velocity would amount to about 100 kilometres per second; but this figure, which does not rest upon exact measures, is of little importance in comparison with the two components we have just discussed.

If we consider these two components as simultaneous—a supposition, moreover, which is well warranted by the phenomena mentioned—we obtain, in uniting them into a single resultant, the prodigious velocity of 1014 kilometres per second, without counting the third component, which is uncertain.

As the component in the line of sight alone so greatly surpasses the potential of the sun, we may conclude that the sun can even now project into space matter which will never return to it.

These observations demonstrate as well that it is impossible to explain according to modern theories the immense disturbances which take place in the atmosphere of the sun by a flow of gas from the interior of the globe.

We are led by these considerations to admit of forces other than atomic motions during the expansion of the gas. Why may we not have recourse to electrical forces, well known by experiment, and which nevertheless produce mysterious results in nature, either by their sudden and unexpected appearance, as in fire-balls, or by their unlimited power in storms?

It is worthy of remark that this region on the sun appeared again on July 1, at the eastern limb, in the same state of violent agitation. At $9^h\ 40^m$, Kalocsa mean time, a prominence appeared, extending from 70° 40′ to 72° 14′ from the celestial pole, or at + 16° 2′ heliographic latitude. It was of medium height, and of dazzling brightness; it was very near the spot, which it partly covered just as the spot came into view. (One point in the mass, at 71° 16′, was the source of a continuous spectrum; a faint band of light extended across the whole field of view; a novel sight which lasted several minutes.)

The light deviated beyond the edge of the slit in the whole extent of this region, toward the red and the blue at the same time. The corresponding velocities were 134 kilometres per second in one direction, and 181 kilometres in the opposite direction.

*This is evidently a misprint in the "Comptes rendus," but in a copy of the paper received from the author it is not corrected. As will be seen from the table, the total ascent of the top of the prominence was 74″.2. G. E. H.

The form of the prominence, which rose immediately to 45″, was easily visible in the red line 6677, in the D_1 and D_2 lines up to an elevation of 11″, and in the lines b_1, b_2 and b_3 to a height of 12″. Other metallic lines were not reversed; the quite common line of barium at 6140.4 was missing, and even the corona line was hardly visible; a surprising fact, when the violence of the eruption is considered. Similarly, the number of lines which I observed on June 17 was not in proportion to the other phenomena.

NOTES ON SOME RECENT SOLAR DISTURBANCES.*

(1) *The bright Solar Prominence of 1891, Sept. 10.*

REV. WALTER SIDGREAVES.

The early part of September was marked by a great revival of solar activity. The largest group of spots witnessed since June, 1885, crossed the sun's disc between Aug. 29 and Sept. 10, in approximate solar latitude 22° N. Its first appearance on the eastern limb was sketched on Aug. 29 in latitude 21° N., and its transit over the western limb was observed both on the screen and in the spectroscope, on Sept. 10, in latitude 22° N. A comparatively small but compact prominence of great brightness was seen through the latter instrument at 0.40 G. M. T. It attained its greatest height, about 35″ of arc, at 1.50; when it assumed the appearance of four blowpipe-jets intensely bright at the bends. This appeared to be the time of its greatest activity, judging by its dimensions, brightness, and rapidity of change. It was watched until 2.15, when the observer had to leave it, and at his return at 3.5 no prominence was visible; but its place on the limb was distinctly marked by the intensity of all the bright lines which had been observed during its appearance: the prominence as such was extinct. Twenty-six bright lines had been counted in all. And of these the usual lines of the chromosphere, C, F, *g* and D_3, were so greatly intensified that the most inexperienced observer could not have failed to see the form of the flame by any one of these colors. The well-known lines in the red, 7055 and 6677 of Angstrom's scale, and D_1, D_2, b_1, b_2, b_3, b_4 and *h* were seen bright almost quite up to the extreme height of the prominence; while the remaining 13 lines glowed only up to about half the average height of the chromosphere. These were not accurately identified but 9 of them were seen between λ 5300 and 5400, and probably belong to the group of iron lines in that region; the other four were seen between the *bb* group and F.

* From The Observatory, October, 1891.

A careful measurement of the spot drawing made earlier in the morning shows that a strong nucleus of a spot group was exactly upon the limb at the time of the spectroscopic observations.

A more detailed account of the group of spots, as observed during its passage, may be given later.* But in connection with the bright prominence it must be noted here that the entire group of spots may be divided into two parts—a preceding and a following sub-group. The first of these was not observed on the limb. It was well over it on the morning of the 10th of September. The preceding part of the following sub-group appears to have been the seat of the observed disturbance, and this was the most active center of the whole group during its passage over the solar disc. Both of the sub-groups were examined with the spectroscope on Aug. 30, Sept. 3 and Sept. 4; when nothing unusual was discovered in the first, while the preceding part of the following sub-group gave evidence of great activity by reversion, distortion, and widening of the C line, on all the three days of observation.

The terrestrial magnetic field may be described as generally more disturbed during the progress of the spot than in the preceding month, and notably at the beginning and end of its course.

But there are no indications of magnetic disturbance accompanying the solar eruptions seen through the spectroscope. Even the brilliant display on the western limb, of the 10th, has left nothing that can be considered a record of itself on the magnetograph curves.

STONYHURST OBSERVATORY, Lancashire.

(*2*) *The Disturbances of 1891, June 17.*

H. H. TURNER.

On 1891, June 17, $10^h\ 9^m$ Greenwich Civil Time, M. Trouvelot projected the solar image on a screen, when his attention was suddenly arrested by an "extraordinary luminous appearance such as he had never seen before."

"Close to the western limb was a bright spot subtending an angle of 3° on the limb greatly surpassing in intensity the most brilliant faculæ he had ever seen. The light was not white as in faculæ, but slightly yellow, very like that of an incandescent lamp just before it acquires its maximum brilliancy . . . . . A minute later there appeared, a little north of this object, a narrow line of

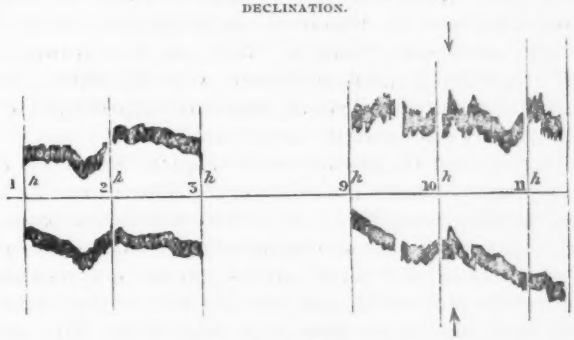
*See paper by Rev. A. L. Cortie, 1891, Nov., *Observatory* p. 363.

facula, parallel to the limb and at a little distance from it, and subtending an arc of 5° to 6°, shining with the same kind of light but not so brilliantly."

After observing these phenomena for a few minutes, M. Trouvelot adjusted the spectroscope on the region and found two prominences, "one at 281° and the other at 286° to 290°." (No further explanation of these figures is given in C. R., No. 25, p. 1420, but from comparison with the photographs, to be presently mentioned, it is inferred that they are angles from N. point in the direction N., E., S., W.). But it soon became evident that the phenomena were diminishing in brilliancy; which was confirmed on removing the spectroscope and again mounting an ocular. "Là, ou quelques minutes plus tôt etincelait une si éblouissante lumière, on ne voyait rien d'inusité, pas même la plus fabiel trace de facule." [We imagine that here M. Trouvelot is referring only to the place formerly occupied by the bright light at first noticed; and does not mean that the facula which appeared a minute later had also disappeared: though this is not quite clear from his words. We shall return to this point immediately.] The spectroscope was replaced and the prominences were found to have undergone some change, but to be nearly as bright as before. Only a few lines were reversed, however: C, D_3, F, and G were very bright; but besides these there was only λ 6676.8, *b*, a line in the blue, and perhaps λ 4394.8. Nothing was seen on D_1 and D_2. M. Trouvelot continued to observe the gradually diminishing spectroscopic phenomena till midday; and again on June 18 from 9^h 20^m till 2^h 35^m, when "le calme est rétabli et toute trace de protubérance éruptive a disparu." In the afternoon of June 17, observations were made quite independently by M. Jules Fényi, at Kalocsa. He refers to the disturbed region (now marked by the facula alone?) as "un groupe de taches en train de se développer à 21° de latitude, qui allait, selon notre calcul, franchir le bord occidental du Soleil à 282° du pôle céleste." But his observations were confiined to the neighboring prominences, whose enormous velocity in the line of sight struck him at once. Careful measurements gave as the value of this velocity 300 to 400 kilometers per second; and the rapid development of the prominence from a height of 111″ to 257″ indicated a velocity of about 500 km. per second transverse to the line of sight. The resultant velocity, even allowing only a moderate component in the third direction, may have at times reached 1000 km. per second! If the appearances are due to matter in

actual motion with such velocity as this, it would of course escape from the Sun's attraction.

In concluding his account of the phenomenon, M. Trouvelot compares it to that simultaneously observed by Carrington and Hodgson (*Monthly Notices*, XX, pp. 13-16) on 1859, Sept. 1, which was accompanied by marked magnetic disturbances; and he asks whether such was also the case on Sept. 17. On examining the Greenwich photographic records, we find a very minute, though unmistakable, disturbance at almost precisely the time noted by Trouvelot. It is not quite clear from his account whether he began observing at $10^h\ 7^m$ ($10^h\ 16^m$, Paris time), or whether the bright spot suddenly appeared then. But it *is* clear that the disappearance was very rapid, and the whole phenomenon very short-lived. Now at $10^h\ 7^m$, within a very small limit of error, there was a sudden small disturbance of all three magnets (registering declination, horizontal force, and vertical force), as will be seen from the appended diagram for 2 of the elements.



The disturbance is smaller than many others on the same day, although the day itself was very quiet; but it differs from others, one of which (at about 3^h) is shown for comparison in its abruptness, which is clearly shown in all three curves. The change in declination is only about 1′, and in H.F. 0.0005 of the whole H.F. We may compare with these the change of 17′ in declination, and 0.0064 of the whole H.F., which took place on 1859, Sept. 1, simultaneously with the Carrington-Hodgson disturbance, and the tremendous magnetic storm which went on for some days, during which the changes were much larger still; and it becomes obvious that the phenomena of June 17 were of an entirely different order of magnitude.

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Two photographs of the Sun were taken at Greenwich curiously near the time of M. Trouvelot's observation—one at $10^h\ 19^m\ 53^s$ G. C. T., and another at $10^h\ 51^m\ 53^s$. Both show the facula described by M. Trouvelot, but there is no trace of anything extraordinary; nor, indeed, should there be, according to M. Trouvelot's account, for the brilliant region had disappeared within a few minute safter $10^h\ 7^m$.

RECENT RESULTS IN SOLAR PROMINENCE PHOTOGRAPHY.

GEORGE E. HALE.

Since the presentation of my last paper on this subject at the meeting of the British Association, solar work has become of much more general interest on account of the publication of two valuable papers by M. Deslandres and Professor C. A. Young. The first of these appeared in the "Comptes rendus" for Aug. 17, 1891,* and described M. Delandres' investigations at the Paris Observatory. Professor Young's "Note on the Chromosphere Spectrum"† was first printed in *Nature*, Nov. 12, 1891. In general the results reached by both of these investigators go to confirm those already published by the writer.

I have recently had the pleasure of visiting M. Delandres at the Paris Observatory, and he has very kindly shown me the apparatus used in his research. I was much gratified to learn how completely my results were confirmed with instruments of a very different kind. In my last paper some hesitancy was expressed in assigning the line close to H, and just above it, to hydrogen, but at present there can be no doubt on this point. The opinion already ventured that the line is due to hydrogen has been borne out by photographs made here, in which the line is strong, and none of the "ghosts" of H and K are visible. The hydrogen lines both above and below H are shown on the same plates, and, apart from the ghost question, there would be no reason to expect that the intermediate line of the series would be missing. Moreover, M. Delandres has photographed the same line with prisms, in which case there could be no trouble from ghosts. Though his dispersion was too small to allow of a crucial test, the exact coincidence of the line with the corresponding one from a hydrogen tube must be regarded as practically settling the matter, when it is also considered that Professor Young has photographed the same line with a grating almost wholly free from ghosts.

*See page 60. †See page 59.

It is curious that in regard to the duplicity of the line hydrogen α (3889)* Professor Young's results differ so widely from my own. He has always found the line single, and therefore concludes that "the companion line makes its appearance only rarely." Out of a very large number of photographs made at this Observatory of the prominence and chromosphere spectrum, the line hydrogen α_1 is shown in but eighteen. In eleven of these, made on five different dates, the line is a sharp and beautiful double, and the duplicity is certainly not the result of poor focusing or ghosts. Professor Rowland has examined the plates, and testified to this last point. Of the other seven plates the duplicity is doubtful in three owing in one case to the breadth of the line, in another to poor focusing on the sun's limb, and in the third to under exposure. Two plates, the first made with radial slit on July 4, 1891, and the other with tangential slit on Oct. 20, 1891, (in the eruption to be described presently) certainly show the line single, only the *upper* component (that due to hydrogen) being present. Certain peculiarities in both of these plates should be mentioned. In that taken with radial slit on July 4 a diaphragm cut off the light for a short distance above the sun's limb, so that only the upper part of the prominence lines is shown. Strange to say, the hydrogen line close to H is hardly, if at all, visible, while the upper component of hydrogen α_1 is fairly strong. In most cases hydrogen α_1 is absent if hydrogen ε (near H) is not well developed, and this is so generally true that the strength of hydrogen ε may be taken as a criterion on which the presence of hydrogen α_1 depends. The photograph taken during the eruption of Oct. 20 is the only one so far obtained in which hydrogen α_1 is shown at the same time that the distortion of K indicates motion in the line of sight. Unfortunately hydrogen ε was out of the field in this photograph, and its relative strength could not be determined. These peculiarities suggest a direction for future study, though it may be that they have nothing to do with the question of duplicity.

In the remaining two plates of the eighteen which show hydrogen α_1 we meet with another condition which complicates the determination of duplicity in these instances. Both exposures were made with a tangential slit slightly overlapping the sun's limb at the point where the second eruption of Oct. 20 was subsiding. The visible spectrum of the chromosphere at the time contained a great many bright lines. In the photographs H, K, hydrogen ε, α_1

*Prof Young has suggested that for the sake of conformity with the publications of Dr. Huggins and others, the Greek letters designating the ultra-violet hydrogen series be written with subscripts; thus the line mentioned above would be α_1, the subscript distinguishing it from α (C).

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and β_1 are strong, and the presence of other lines is suspected, though the rapid widening of the strip of spectrum toward the ultra-violet makes it impossible to be certain. H and K are remarkably strong, and in one of the plates hydrogen α_1 also extends across and beyond the strip caused by the slit overlapping the limb. In the center of the bright H and K lines the dark reversal is very prominent at the middle of the strip, but at the edges the dark line disappears. Both H and K are thus single and tapering at the ends, and expand at the center, where they each enclose a dark line. But it is of interest to note that hydrogen α_1 is affected in precisely the same manner, while hydrogen ε shows no sign of the central dark reversal. As the latter line appeared, however, on only one plate, it would be hasty to draw any conclusions at present. But in the case of hydrogen α_1 we certainly seem to have a true reversal, for if the separation at the middle of the strip were due to the duplicity of the line it would extend to the edges, and this does not seem to be so. The distance between the components of α_1 when double in the ordinary way, as determined on a comparator, is about two-thirds the distance between the separated portions of the apparent reversal. Moreover, the upper component of α_1 falls exactly on the more refrangible portion of the reversed line; thus the lower component of α_1 is probably not present, for if it were it would be seen to overlap the dark center of the reversal. It is hoped that further photographs will provide material for a complete study of this question.

When we examine the components of the double α_1 line in a number of plates, we find in almost every case that the (more refrangible) line due to hydrogen is quite sharply defined at the edges, and seems to fall exactly upon a bright space in the solar spectrum. At times it is even difficult to be sure whether the line is present, as under certain conditions the ultra-violet hydrogen lines in a prominence are very faint, and the bright space in which α_1 falls remains of sensibly the same intensity. The less refrangible component is nearly always fainter, broader, and less sharply defined at the edges than its companion. It does not seem probable that it is due to hydrogen, as no trace of it has been recorded in laboratory investigations of this spectrum. No evidence of duplicity of this line has been found in photographs of stellar spectra, but up to the present time sufficient resolving power has not been employed in this part of a star's spectrum. In two instances hydrogen ε (near H) and hydrogen α_1 have been bright through enough to show the form of prominences photographed a widely opened slit.

There seems to the writer every reason to ascribe both H and K in the prominences to calcium, at least in so far as we may depend upon the coincidence of the lines with those given by calcium in the arc, spark or flame. Negatives recently made here show a most perfect agreement of the dark lines in the solar spectrum with the bright lines in prominences not affected by motion in the line of sight, and Professor Rowland, using enormous dispersion, has found the dark lines in question to coincide exactly with the calcium lines given by short exposure to the arc. The calcium line at λ 4226.3, though carefully searched for, has not been found in the prominence spectrum, but Professor Rowland has recently informed me that in appearance and behavior in the arc this line is entirely different from H and K. Its absence from the prominences is therefore not greatly to be wondered at. I hope soon to determine the position of the bright H and K lines with an observing telescope of twice the focal length of that now employed. At the same time I cannot share in the doubts expressed by Professor Young in regard to the origin of the lines, and have little hesitation in ascribing them to calcium.

The relative intensities and heights of H and K have been compared in a large number of plates, the result being that K is almost invariably more intense (and higher when radial slit is used) than H. In one or two cases the intensities seem to be about equal, or even incline toward a greater intensity for H, but this is yet to be established. A prominence seems to have about the same form in both lines, and distortions due to motion in the line of sight in all plates so far examined differ but little. Where differences exist, they may presumably be ascribed to the usually greater brightness of K. These points are well illustrated in Plate IV. The expansion of H and K where the base of a prominence merges into the chromosphere has been mentioned in a previous paper. A recent photograph supplements the evidence thus afforded by the radial slit. In it the slit is tangential, and lies across the chromosphere, just in contact with the limb, though not overlapping it. On either side of the point of tangency a prominence rose high enough to be cut by the slit. In the photograph the chromosphere reversals are more than twice as broad as the narrow and more sharply defined prominence lines.

In my last paper mention was made of a solar eruption photographed by my brother and sister, W. B. Hale and Martha D. Hale, who were engaged in the regular work of the Observatory during my absence. Inquiry was made of M. Tacchini, M. Trouvelot, and others, but no record of the eruption other than

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that made here could be found. I have recently received a letter from Herr Julius Fènyi, S. J., Director of the Haynald Observatory at Kalocsa, Hungary, which is of such interest in this connection that, with his permission, a translation is given below:

"I think that it will be very interesting to you to learn that the sudden formation of a prominence observed at your 'scientific institute' on July 8, 1891, at $23^h\ 45^m$, Chicago M. T., and mentioned in your very interesting article in 'Memorie degli Spettroscopisti' on 'The Ultra-Violet Spectrum of the Solar Prominences,' was by a singular chance also observed simultaneously in Kalocsa. The observation was first possible, on July 9, at 7^h P. M. Enclosed I send for comparison a copy of the drawing of the form made at the telescope at the time. The height was measured by means of transits across the slit between $7^h\ 4\frac{1}{2}^m$ and about $7^h\ 6^m$, and found to be 204″, in excellent agreement with your determination of 80,000 miles. In the journal of observations it is recorded that at $7^h\ 19^m$ (Kalocsa M. T.) the projection (at 69°) had almost entirely disappeared, only a few very faint fragments remaining. As Kalocsa — Chicago $= 7^h\ 6^m$ you observed the uprush according to your statement on July 9, $11^h\ 45^m$, Chicago M. T. or July 9, $6^h\ 51^m$ Kalocsa M. T. My drawing and measure of position were finished at about $7^h\ 0^m$, after which the transits were taken, which were soon disturbed by clouds. The observations must thus have been made at exactly the same time.

"This phenomenon, remarkable in itself for its unusually great size, arouses a particular interest because of its relation to a spot-group at that time on the other side of the sun. It is at this remarkable place on the sun where, ever since May, such magnificent phenomena and constant eruptions have happened. I am just sending an article to M. P. Tacchini on the extraordinary phenomena observed on July 24 at this place on the sun (west limb). As this region passed over the limb on July 11, I also observed an important eruption there; the point is marked on the drawing (which accompanied the letter) by a red cross. These places are of course given on the drawing only as the result of accurate calculation.

"I therefore believe that the great prominence observed on July 9 was the product of an eruption rising from *this spot region*, or perhaps not far from the nearest great spot, and that what we saw was only that part of the far-reaching mass of the prominence which extended above the sun's limb. The fact that I saw no metallic lines supports this view, as these usually appear only at the base. If this great prominence had been at

the place of the eruption of July 11, it would have been distant 24°.6 from the limb; the reduction of its apparent height would have amounted to 98″. I observed with a 7-in. refractor and a 6 prism automatic spectroscope by Hilger, in the C line.

"The places mentioned are at the following heliographic positions:

"Eruption of July 11, $4^h\ 12^m$ P. M. Kalocsa M. T.; heliographic latitude + 17°.2 to 22°.8; longitude 124°:

"Prominence of July 9, 7^h P. M.; latitude 21°.7 to 29°.8; longitude 149°."

It is certainly a remarkable coincidence that simultaneous observations of an eruption lasting but about 15 minutes should have been made from stations so widely separated. The more so from the fact that the sun's limb must be examined piecemeal by the spectroscopist, and but a small portion can be seen at a single position of the instrument. By a mistake in the paper mentioned by Herr Fényi Central Time was recorded as Chicago Mean Time. Adding the necessary correction it is found that the photograph reproduced in Plate III* for comparison with Herr Fényi's drawing was made at $11^h\ 55^m$ Chicago M. T., or $7^h\ 1^m$ Kalocsa M. T. It will be seen that the photographs made in H and K, though very poorly reproduced by the process employed, show a striking agreement with Herr Fényi's drawing. The photograph, moreover, does what the eye could not do, for it shows the part played in the prominence by calcium, while for the drawing the hydrogen line C was used. A photograph of the spectrum of the prominence with radial slit was made here at $11^h\ 45^m$ Chicago M. T., or 10^m before that of the form. Hand K are the only bright lines shown; even hydrogen ϵ (near H) is absent. Both H and K are distorted toward the red, and indicate a velocity of about 58 miles per second away from the earth. Drawings were made here before, during, and after the eruption, which was estimated to have lasted about 15 minutes. Two hours later the form and spectrum of the remaining portion of the base of the prominence were also photographed. Very little remained at this time, but it is interesting to note that in addition to H and K, hydrogen ϵ and α_1 (double) are present. As they extend but a short distance from the limb it is possible that their absence in the photograph made during the eruption may thus be accounted for, as the limb was then covered by a diaphragm. The eruption seen by Herr Fényi on July 11 was missed here on account of clouds. The suggestion that the

*See plate preceding p. 17.

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eruption of July 9 had its origin in the spot-group which did not arrive on the limb until July 11 does not seem an improbable one. At the same time the absence of metallic lines is hardly a convincing argument in its favor, as they do not seem to be the invariable accompaniments of such eruptions.

On Oct. 20, 1891, I observed and photographed two interesting eruptions at 114°. At $10^h\ 35^m$ A. M., Chicago M. T., I was looking for prominences with an annular slit, which allowed about 90° on the limb to be seen at once, and suddenly noticed some bright filaments at a considerable distance from the limb. The annular slit was immediately replaced by the straight one ordinarily employed. With this open to its fullest extent an explosive prominence was seen rising in detached vertical filaments to an elevation of about 4′ 15″ or 107,000 miles. Light clouds soon covered the sky, and photographs of the spectrum only were made. The prominence, as observed through C, changed rapidly in form, but no lines were seen in its spectrum other than C, D_3, and F, the latter being very faint. A line was seen for a short time just above D_3, and about one-quarter the distance between D_1 and D_2 away from it, but it may have been a ghost of D_3. In the photographs of the spectrum only H and K are present, hydrogen ε and α_1, as might be expected from the faintness of F, being absent. The distortion of H and K in all the photographs is toward the violet, as is shown by the lower figure of Plate IV,* which is enlarged about three times from the original negative, without retouching. The velocity toward the earth, as measured from the maximum displacement of K in this plate, is about 64 miles per second. At $11^h\ 48^m$ I returned to the telescope, after having been absent a few minutes in the dark-room. The great filamentous prominence had disappeared, and in its place was seen a long chain of bright prominences about 1′ high, which changed rapidly, and showed some distortion in C. In the spectrum of the chromosphere at the base F was very bright, the *b* lines reversed, but D_1 and D_2 were unaffected. A photograph with the slit tangent at this point does not show hydrogen α_1 bright, a point to be noted in connection with the unusual brightness of F. K was of course reversed, but H and hydrogen ε were beyond the edge of the plate.

Observations were resumed at $2^h\ 15^m$, when I was surprised to find that the long line of low prominences had completely disappeared, giving place to a beautiful column rising to a height of about 2′, and instantly reminding me of the eruption of a great geyser. C and D_3 were somewhat distorted toward the violet,

*See plate preceding p. 17.

F was fairly bright, and the *b* lines were not reversed. The upper part of the prominence appeared like a cloud of spray blown out by a violent wind; it was seen to be falling rapidly, and in about fifteen minutes the end had met the chromosphere. The photograph used for the illustration in plate IV was made at $2^h\ 30^m$. In reproducing it no retouching was allowed, so that though much of the detail and contrast of the original negative were unavoidably lost, the result is a picture in which no personal bias enters, as it is the outcome of purely photographic processes. The illustration is about three times the size of the original. It will be seen that the image in H is not nearly as good as that in K, probably on account of the greater brightness of the latter. The form is very similar to that shown in a drawing made about the same time through C. The slit was very wide, and even with the convenient broad bands in this region of the spectrum proper contrast was difficult to obtain.

At $3^h\ 28^m$ the prominence was seen to be breaking up, and a few minutes later the chromosphere at the base was found to contain a great number of bright lines, including D_1, D_2, D_3 (*brilliant*), b_1, b_2, b_3, b_4, and many others. The photographs mentioned on page 00 as showing a_1 reversed, were made at this time. The sun was so low that observation had to be given up at $4^h\ 28^m$, and the numerous chromosphere reversals could not be recorded. When last seen the prominence was greatly broken up, and bore no resemblance to the form shown in the photograph made two hours earlier.

On the following day a group of rather bright faculæ was seen near where the two eruptions occurred. Two bright and fairly active prominences were on the limb at the same position angle. On Oct. 22 two spots with bright faculæ had advanced on to the disc at this point. With a wide slit a small bright prominence was seen on the disc near the larger spot, and extending over part of the surrounding region.

In his paper in the "Comptes rendus," a translation of which is given on another page,* M. Deslandres has objected to the methods of prominence photography proposed some time ago by the writer, because theyseem to apply only to single prominences and not to the whole circumference of the sun. Of some of the earlier schemes devised the criticism is a sound one, but when the apparatus mentioned in my last paper is completed it is believed that its range will be much less limited. In a paper published in 1890 I proposed that a series of photographs of prominences be

* Page 60.

taken at equal intervals of time, thus giving a means of determining their velocities in two directions. For the velocity in the third direction—the line of sight—a series of photographs with narrow slit should be taken simultaneously with the others, the exact time of exposure being noted in all cases. Thus the true motion of a prominence may readily be determined. It is evident that for motions in certain directions a correction for the effect of aberration must be introduced, as M. Fizeau has pointed out,* when the accuracy of the measures is great enough to require it.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, December 14, 1891.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 96 for information in regard to illustrations, etc.

Dr. Henry Crew writes from the Lick Observatory of a very persistent prominence observed there on Nov. 26, 27 and 28, 1891. It appeared on the western limb of the sun, near the equator, just where two spots went off on Nov. 26. Its changes in form were very gradual, and when last seen on Nov. 28 it appeared to be breaking up. The spectrum of this prominence was photographed at the Kenwood Observatory on Nov. 26, but cloudy weather prevented us from taking any photographs of the form, which would have been valuable for comparison with Dr. Crew's drawings. His observations were made with the 6-inch telescope, as no definition is obtainable with the 36-inch during the daytime.

The reception given by Mrs. Henry Draper to the members of the National Academy of Sciences on the occasion of its recent meeting in New York was in every respect most enjoyable. In the laboratory, so long used by Dr. Draper in his spectroscopic investigations, Professor E. C. Pickering gave an illustrated lecture on the recent advances in the work of the Henry Draper Memorial. Of the magnitude and importance of this work nothing need be said here. Certainly no better or more lasting memorial could be raised to a scientist.

The universal spectroscope just completed by Brashear for Professor Young is probably the most perfect instrument of its kind in use. It is expected that a fully illustrated description of it may soon be printed as one of the papers in our series on "The Modern Spectroscope."

The Paris Observatory is to be congratulated on having a most efficient head for its spectroscopic department in the person of M. Henri Deslandres. The work already accomplished by this skillful investigator is of the highest order, and additional important results may confidently be looked for in the course of his re-

* See or "Comptes rendus" Sept. 7, 1891.

searches. In addition to his study of the prominence spectrum with the Foucault siderostat some successful experiments have been undertaken on stellar motion in the line of sight, and the four-foot reflector is being re-mounted for a continuation of this work.

The spectrograph at the Potsdam Observatory has been dismounted for some time, as the motions of all stars within the capacity of the telescope have been already determined. An effort is being made to secure a 30-inch refractor with a new spectroscope, in order to include much fainter stars in the investigation. Professor Vogel will probably visit this country during the coming summer to examine the construction of the Lick telescope and other large instruments.

Professor Rowland will soon publish a list of the wave-lengths of 1000 standard lines, to accompany his photographic map of the solar spectrum. Such a list will be universally welcomed by spectroscopists, as it will remove all the difficulties hitherto encountered in the use of the map. A third dividing-engine for ruling gratings is just being completed and Professor Rowland already has in mind a concave grating of so large a size that it can be used directly for stellar spectra, without a telescope. If such an instrument could be made it would possess many important advantages. At present, however, a good 6-inch concave grating is so difficult to obtain that we may have to wait a long time for anything larger.

The powerful carbon disulphide spectroscope at the Nice Observatory still stands just as it was left at M. Thollon's death. No one has yet been found to take up the spectroscopic work at Mont Gros, and it does not seen likely that the great map of the solar spectrum, which was more than half finished by M. Thollon, will be completed for some time to come. M. Cornu is devising a new spectroscope, which will be fitted to the 30-inch refractor for stellar work.

Dr. and Mrs. Huggins, with their untiring energy, are at work on the visual spectrum of the Great Nebula in Andromeda, and they hope soon to prepare a paper embodying their results. Anyone who has examined this excessively faint spectrum will appreciate the very great difficulty of the work. Dr. and Mrs. Huggins observe independently, and each makes a full record in the note-book without knowing what the other has seen. Thus entire freedom from personal bias is secured. With the pain-staking care put into their work, it is not surprising that their observations have the highest reputation for excellence and reliability.

We have recently received from Rev. Walter Sidgreaves, of Stonyhurst Observatory an enlargement on paper of the group *b* in the solar spectrum. It was made with a 14,438 Rowland plane grating, and shows remarkably good definition. The scale is somewhat greater than that of Rowland's map, which is surpassed in the number of faint lines shown. In fact, some lines seem to be present which are not found on Thollon's great map of this region. But in spite of such excellent definition "line No. 17 of Mr. Winlock's maps (Proceedings of American Academy) is so faint on all my negatives that it can only just be discovered with a very careful search." Have we here an indication of variability in the intensity of a line? It is almost to be expected that cases of certain variability would be established if a sufficiently thorough and prolonged investigation were undertaken. The endless variety of stellar spectra clearly indicate important changes during the process of evolution from nebula to star, and in the course of years we may be able to draw valuable conclusions from variations in solar lines. In addition to gradual changes, it is by no means impossible that there may be temporary variations in absorptive power due to differences in spot or prominence activity.

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CURRENT CELESTIAL PHENOMENA.

Our plan in conducting this department of ASTRONOMY AND ASTRO-PHYSICS will be essentially the same as that pursued in THE SIDEREAL MESSENGER. We shall aim to give notice, one month in advance, of the predicted phenomena for each month, and also to state briefly the results of observations which are reported.

It seems best to give the times of phenomena in civil time and to adopt the standard time system in common use in the United States. Central time, which will be generally used, is the time of the 90° meridian from Greenwich, which passes through the central part of the United States. The standard times of rising and setting of the planets vary with the place of the observer. They are calculated for the 90th meridian, and latitude 44° 28′. For other places not differing greatly in latitude the approximate standard times will be obtained by adding or subtracting the difference between local and standard time at the place of observation.

The times of occultations of stars by the moon, which also vary considerably with the latitude and longitude of the observer, are given in Washington time for the meridian of Washington, the data being taken without change from the American Ephemeris.

Ephemerides of comets will be given one month in advance when possible. In every case the latest and most accurate data available will be used.

PLANET NOTES FOR FEBRUARY.

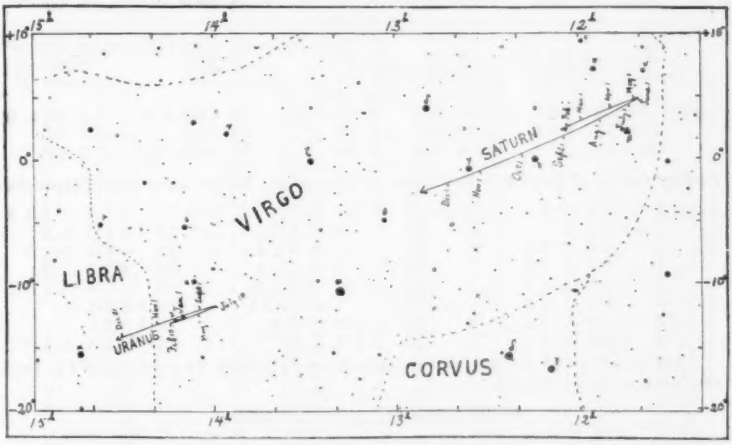
Mercury during February will be west of the sun, and too close to the rays of the latter to be seen with the naked eye. Daylight observations of its gibbous phase may be obtained by those having use of large telescopes.

Venus and *Jupiter* are the two brilliant "evening stars" in the southwest, Venus the more brilliant of the two. On the morning of Feb. 6, while they are invisible from this part of the world, these two planets will be in conjunction. They will be so close together that the unaided eye would be unable to separate them, and possibly, if an observer on the other side of the earth is able to watch them with a telescope, he will see an occultation of Jupiter by Venus. After this Venus will move eastward, so that at the end of the month they will be about 20° apart.

In another place Mr. Barnard calls attention to the fact that the new large red spot, which lately appeared in the second dark belt south of Jupiter's equator, has disappeared; also that the small dark spots on the edge of one of the northern belts have developed into a new narrow belt. The great red spot became more conspicuous this year than last and is now a striking object upon the planet. There have been changes also in the white equatorial belt. A very narrow dark belt was observed almost exactly on the equator on several nights in September. On December 17 this was invisible but the whole equatorial belt was far from white and was filled with dusky cloud forms, most of them curving backward from the belts on either side toward the equator, and toward the east limb of the planet. The great red spot and a small but brilliant white spot, just skirting its southern edge, passed the central meridian of Jupiter together at 4:44 P. M., central time, Dec. 17.

Mars will be visible in the morning, in the southeast, after 3 A. M. He will in February pass from the constellation Scorpio into that of Ophiuchus. He will be a few degrees northeast of the red star Antares, which star, however, Mars exceeds both in redness and brilliancy.

Saturn may now be observed after midnight and in February will begin to be in good position during the later evening hours. The accompanying chart will give some idea of its path among the stars during the year. He is in the constellation Virgo and will move westward until May 26, after which for the remainder of the year his motion will be eastward. In November he will pass near the fine double star γ Virginis.



Uranus may be found farther down toward the eastern horizon after midnight. His course among the stars for the year is platted on the same chart with that of Saturn. Just now he is moving eastward but on Feb. 9 will turn and move westward until July 9, after which, his course will again be eastward for the remainder of the year. He will thus pass three times very close to the fifth magnitude star λ Virginis. The three conjunctions with this star will occur Jan. 3, Mar. 20 and Oct. 14.

Neptune will still be in good position for observation during the early evening. Neptune will be stationary in right ascension Feb. 15, and after that will move slowly eastward. For chart of his path among the stars see SIDEREAL MESSENGER, page 463, Nov. 1891.

MERCURY.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Feb. 5.....	19 55.2	−21 53	6 23 A. M.	10 54.0 A. M.	3 25 P. M.
15.....	20 59.5	−19 03	6 34 "	11 18.7 "	4 03 "
25.....	22 06.3	−13 56	6 38 "	11 46.0 "	4 54 "

VENUS.

Feb. 5.....	23 25.0	− 5 01	8 40 A. M.	2 23.1 P. M.	8 07 P. M.
15.....	0 09.1	+ 0 13	8 24 "	2 27.8 "	8 32 "
25.....	0 52.5	+ 5 26	8 07 "	2 31.8 "	8 57 "

MARS.

Feb. 5	16 22.3	−21 02	2 46 A. M.	7 21.6 A. M.	11 57 A. M.
15.....	16 48.6	−22 03	2 38 "	7 08.6 "	11 39 "
25.....	17 15.0	−22 48	2 29 "	6 55.6 "	11 22 "

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Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
		JUPITER.			
Feb. 5	23 27.1	— 4 47	8 40 A. M.	2 25.2 P. M.	8 10 P. M.
15	23 35.4	— 3 51	8 06 "	1 54.2 "	7 42 "
25	23 43.9	— 2 55	7 31 "	1 23.4 "	7 15 "
		SATURN.			
Feb. 5	12 1.9	+ 2 25	8 45 P. M.	2 58.1 A. M.	9 11 A. M.
15	12 00.0	+ 2 40	8 03 "	2 16.8 "	8 31 "
25	11 51.6	+ 2 57	7 20 "	1 35.2 "	7 50 "
		URANUS.			
Feb. 5	14 15.7	—13 5	12 04 A. M.	5 15 3 A. M.	10 26 A. M.
15	14 15.6	—13 4	11 21 P. M.	4 32.0 "	9 43 "
25	14 15.2	—13 2	10 42 "	3 52.3 "	9 03 "
		NEPTUNE.			
Feb. 5	4 18.8	+19 48	11 50 A. M.	7 16.2 P. M.	2 43 A. M.
15	4 18.7	+19 48	11 10 "	6 36.7 "	2 03 "
25	4 18.8	+19 49	10 31 "	5 57.5 "	1 24 "
		THE SUN.			
Feb. 5	21 15.7	—15 55	7 15 A. M.	12 14.2 P. M.	5 14 P. M.
15	21 55.2	—12 40	7 01 "	12 14.3 "	5 28 "
25	22 33.6	— 9 04	6 45 "	12 13.3 "	5 42 "

Configuration of Jupiter's Satellites at 7:30 p. m. for an Inverting Telescope.

Feb. 1	3 4 2 ○ 1	Feb. 9	3 2 1 ○ 4	Feb. 17	3 ○ 4 1 2
	2 4 3 1 2 ○	10	3 ○ 1 2 4	18	4 1 3 ○ 2
3	4 3 ○ 1 2	11	1 ○ 3 2 4	19	4 2 ○ 1 3
4	4 1 ○ 2 3	12	2 ○ 1 3 4	20	4 1 2 ○ 3
5	4 2 ○ 1 3	13	1 ○ 3 4 ●	21	4 ○ 1 3 2
6	4 1 ○ 2 3	14	○ 1 3 2 4	22	4 3 2 1 ○
7	4 ○ 3 2 ☌	15	3 2 ○ 4 ●	23	4 3 2 1 ○
8	3 4 2 ○ 1	16	3 2 1 ○ 4	24	4 3 ○ 1 2

The Satellites of Jupiter are invisible from February 24 until April 17, Jupiter being too near the sun.

Phenomena of Jupiter's Satellites.

	h m				h m		
Jan. 16	4 20 P. M.	I.	Ec. Re.	Jan. 31	4 34 P. M.	I.	Tr. Eg.
17	5 51 "	III.	Sh. Eg.		5 23 "	I.	Sh. Eg.
19	6 57 "	II.	Oc. Dis.		7 20 "	III.	Tr. In.
21	4 52 "	II.	Tr. Eg.	Feb. 4	7 37 "	II.	Tr. In.
	6 51 "	II.	Sh. Eg.	6	6 20 "	II.	Ec. Re.
22	5 44 "	I.	Tr. In.	7	5 02 "	I.	Sh. In.
	6 42 "	I.	Sh. In.		6 36 "	I.	Tr. Eg.
	8 02 "	I.	Tr. Eg.	8	4 34 "	I.	Ec. Re.
23	4 51 "	IV.	Oc. Re.	9	4 53 "	IV.	Ec. Dis.
	6 15 "	I.	Ec. Re.	13	4 56 "	II.	Oc. Dis.
24	6 16 "	III.	Tr. Eg.	14	6 21 "	I.	Tr. In.
	6 46 "	III.	Sh. In.	15	6 29 "	I.	Ec. Re.
28	4 48 "	II.	Tr. In.	18	6 31 "	III.	Oc. Dis.
	6 38 "	II.	Sh. In.	22	5 32 "	II.	Tr. Eg.
	7 39 "	II.	Tr. Eg.		5 41 "	I.	Oc. Dis.
29	7 46 "	I.	Tr. In.		6 29 "	II.	Sh. Eg.
30	5 04 "	I.	Oc. Dis.	23	5 12 "	I.	Tr. Eg.
	8 10 "	I.	Ec. Re.		5 39 "	I.	Sh. Eg.

Approximate Central Times when the Great Red Spot passes the Central Meridian of Jupiter.

	h m		h m		h m		h m
Feb. 1	2 34 P. M.	Feb. 7	7 58 P. M.	Feb. 13	2 38 P. M.	Feb. 19	7 33 P. M.
2	8 30 "	8	3 30 "	14	8 25 "	20	3 24 "
3	4 21 "	9	9 17 "	15	4 16 "	21	9 11 "
4	10 08 "	10	5 08 "	16	10 03 "	22	5 02 "
5	6 09 "	11	1 09 "	17	5 54 "	23	12 55 "
6	1 51 "	12	6 45 "	18	1 46 "	24	5 41 "

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Nov. 1891.]

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abbreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

Jan. 1892.		Jan. 1892.		Jan. 1892.		Jan. 1892.	
15	4.2 pm Di dn	20	5.0 pm Rh ds	26	6.5 am Te es	31	11.0 pm Titan an
	6.4 Di en		5.6 Te Sh		5.1 pm Di en	Feb.	
	7.7 Mi as		5.7 Rh Sh		8.8 En an	1	12.4 am Te ds
	9.4 Te an		6.2 Mi an		9.2 Mi es		1.5 Te Sh
	9.7 En an		7.5 Te bs	27	3.1 am Mi as		1.5 Mi an
	10.8 Te Ecl. D		8.9 Rh bs		3.1 En en		2.3 Di dn
	11.7 Titan Ecl. D		9.5 Te as		5.2 Te an		3.3 Te bs
16	1.1 am Mi an		10.1 Di an		6.7 Te Ecl. D		3.9 Rh dn
	2.1 Rh es		11.2 En as		3.5 pm Rh dn		4.1 Titan Ecl.R
	2.3 Te dn		11.5 Rh as		6.0 Rh en		4.5 Di en
	4.1 En en		11.5 Di Ecl. D		6.3 Di es		5.3 Te as
	4.3 Te en	21	12.1 am Mi en		7.6 En as		5.8 Titan c
	4.7 Rh ds		3.6 Di dn		7.8 Mi es		10".6 n
	5.1 Titan Ecl. R		5.5 Mi es		8.5 Di ds		6.4 Rh en
	5.3 Rh Sh		5.8 Di en		9.5 Di Sh		6.7 pm Mi as
	7.0 Mi en		6.2 pm Te dn		11.8 Di bs		9.1 Te an
	7.5 Titan c 11".1 n		8.2 Te en	28	1.7 am Mi as		10.6 Te Ecl. D
	8.5 Rh bs		10.7 Mi en		2.0 Di as	2	12.1 am Mi an
	10.5 Titan dn	22	1.7 am En es		3.8 Te es		12.7 En es
	6.3 pm Mi as		4.1 Mi es		5.7 En an		2.0 Te dn
	7.6 Di es		6.9 Di es		5.8 Te ds		4.0 Te en
	8.0 Te es		4 8 pm Te bs		6.9 Te Sh		5.6 Di es
	8.5 En as		6.1 En an		6.4 pm Mi es		5.2 pm En an
	9.8 Di ds		6.8 Te as		10.1 En es		5.4 Mi as
	10.0 Te ds		8.7 Rh an	29	12.3 am Mi as		7.7 Te es
	10.7 Di Sh		9.3 Mi en		2.5 Te an		9.7 Te ds
	11.0 Te Sh		9.9 Rh Ecl. D		3.1 Di an		10.8 Mi an
	11.7 Mi an	23	12.5 am En en		4.0 Te Ecl. D		10.8 Te Sh
17	12.9 am Te bs		2.7 Mi es		4.4 En as		11.5 En en
	1.1 Di bs		3.1 Rh dn		4.6 Di Ecl. D	3	12.6 am Te bs
	2.9 Te as		5.7 Rh en		5.7 Mi an		2.6 Te as
	3.3 Di as		4.9 pm En as		7 4 Te dn		3.6 Rh es
	6.7 pm Te an		5.0 Titan es		3.2 pm Rh es		4.7 Mi en
	8.1 Te Ecl. D		5.2 Di Ecl. D		5.0 Mi es		6.2 Rh ds
	10.3 Mi an		5.5 Te en		5.8 Rh ds		7.1 Rh Sh
	11.1 En es		7.3 Titan Sh		6.6 Rh Sh		4.0 pm En as
	11.6 Te dn		7.9 Mi en.		8.9 En en		4.0 Di Ecl. D
18	1.6 am Te en		8.8 Titan ds		9.7 Rh bs		4.0 Mi as
	4.2 Mi en		9.3 Di dn		10.9 Mi as		6.4 Te an
	4.4 Di an		11.5 Di en	30	12.2 am Rh as		7.9 Te Ecl. D
	5.4 En as		11.8 Titan e 10".8 s		1.1 Te es		7.9 Di dn
	5.8 Di Ecl. D	24	1.3 am Mi es		3.1 Te ds		9.4 Mi an
	5.3 pm Rh en		2.7 Titan bs		4.2 Te Sh		10.1 Di en
	5.3 Te es		3.0 En an		4.3 Mi an		11.3 Te dn
	7.3 Te ds		6.5 Titan as		6.0 Te bs	4	1.3 am Te en
	8.3 Te Sh		6.5 pm Mi en		5.4 pm Di bs		2.1 En an
	8.9 Mi an		7.5 En es		7.6 Di as		3.3 Mi en
	9.8 En en		11.9 Mi es		9.5 Mi as		5.0 pm Te es
	10.2 Te bs	25	12.6 am Di es		11.4 En an		6.5 En es
19	12.2 am Te as		1.8 En as		11.8 Te an		7.0 Te ds
	4.0 pm Te an		2.8 Di ds	31	1.3 am Te Ecl. D		8.0 Mi an
	4.4 Di Sh		2.9 Rh es		2.9 Mi an		8.1 Te Sh
	5.4 Te Ecl. D		3.8 Di Sh		4.7 Te dn		9.9 Te bs
	6.8 Di bs		5.4 Rh ds		5.8 En en		11.3 Di es
	7.5 Mi an		5.8 Mi as		6.7 Te en		11.9 Te as
	8.9 Te dn		6.1 Di bs		8.1 pm Mi as	5	12.8 am En as
	9.0 Di as		6.2 Rh Sh		8.8 Di an		1.5 Di ds
	10.9 Te en		7.9 Te an		9.4 Rh an		1.9 Mi en
20	12.4 am En an		6.2 pm En en		10.2 En as		2.5 Di Sh
	1.5 Mi en		10.5 Mi es		10.3 Di Ecl. D		4.8 Di bs
	4.6 pm Te ds	26	4.3 am En es		10.4 Te es		5.7 pm Te an
	4.8 En es		4.5 Mi as		10.8 Rh Ecl. D		4.2 Rh dn
					11.0 Titan Ecl.D		5.2 Te Ecl. D

XUM

Feb. 1892.		Feb. 1892.		Feb. 1892.		Feb. 1892.	
5	5.3 pm En en	7	7.1 pm Di ds	9	4.6 am Titan as		6.2 Te es
	6.6 Mi an		7.5 Rh Sh		3.2 pm Te dn		6.9 Rh ds
	6.8 Rh en		7.9 Te en		5.9 Te en		8.2 pm Mi es
	8.6 Te dn		8.2 Di Sh		7.0 Mi en		11.8 En es
	10.6 Te en		9.7 Mi en		7.9 En en	13	2.1 am Mi as
6	12.5 am Mi en		10.4 Rh bs		10.1 Rh an		4.3 Di es
	3.4 En es		10.4 Di bs		11.8 Rh Ecl. D		4.8 Te an
	5.9 Mi es	8	12.6 am Di as	10	12.4 am Mi es		4.2 pm En an
	3.8 pm Di en		1.0 Rh as		4.6 Rh dn		6.8 Mi es
	4.3 Te ds		3.1 Mi es		3.8 pm Te as		10.5 En en
	5.2 Mi an		4.7 En an		4.1 Di bs	14	12.7 am Mi as
	5.4 Te Sh		3.1 pm Titan es		5.6 Mi en		3.5 Te es
	7.2 Te bs		4.5 Te bs		6.3 Di as		5.5 Te ds
	7.8 En an		6.4 Titan Sh		10.4 En an		4.9 pm Rh dn
	9.2 Te as		6.5 Te as		11.0 Mi es		5.4 Mi es
	11.1 Mi en		6.9 Titan ds	11	4.8 am En en		6.6 Di dn
7	2.1 am En en		8.4 Mi en		4.9 Mi as		7.5 Rh en
	4.5 Mi en		9.1 En es		7.4 pm Di an		8.8 Di en
	2.5 pm Te Ecl. D		9.9 Titan c		9.1 Di Ecl. D		11.3 Mi as
	3.8 Mi an		9.9 s		9.2 En as	15	1.1 am En an
	4.0 Rh es	9	12.8 am Titan bs		9.6 Mi es		2.1 Te an
	4.9 Di es		1.8 Mi es	12	12.9 am Di dn		3.8 Te Ecl. D
	5.9 Te dn		1.8 Di an		3.1 Di en		5.5 pm En es
	6.5 Rh ds		3.4 Di Ecl. D		3.5 Mi as		9.9 Di es
	6.6 En as		3.5 En as		4.3 Rh es		10.0 Mi as

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A.....$0^h\ 52^m\ 32^s$
Decl.....$+ 81°\ 17'$
Period.....$2d\ 11^h\ 50^m$

Feb.	1	midn.
	6	"
	11	11 P. M.
	16	11 "
	21	11 "
	26	10 "

ALGOL.

R. A.....$3^h\ 01^m\ 01^s$
Decl.....$+ 40°\ 32'$
Period.....$2d\ 20^h\ 49^m$

Feb.	8	5 A. M.
	11	2 "
	13	11 P. M.
	16	8 "
	19	5 "

R CANIS MAJ.

R. A.....$7^h\ 14^m\ 30^s$
Decl.....$- 16°\ 11'$
Period.....$1d\ 03^h\ 16^m$

Feb.	1	3 A. M.
	7	7 P. M.
	8	10 "
	10	2 A. M.
	11	5 "
	16	9 P. M.
	17	midn.
	19	3 A. M.

R CANIS MAJ., CONT.

Feb.	24	8 P. M.
	25	11 "
	27	2 A. M.
	28	6 "

S CANCRI.

R. A.....$8^h\ 37^m\ 39^s$
Decl.....$+ 19°\ 26^m$
Period.....$9d\ 11^h\ 38^m$

Feb.	6	7 P. M.
	25	7 "

S ANTLIÆ.

R. A.....$9^h\ 27^m\ 30^s$
Decl.....$- 28°\ 09'$
Period.....$0d\ 07^h\ 47^m$

Feb.	2	8 P. M.
	3	4 A. M.
	4	3 "
	5	2 "
	6	2 "
	7	1 "
	7	midn.
	8	11 P. M.
	9	11 "
	10	10 "
	11	9 "
	12	9 "
	13	8 "
	14	3 A. M.
	15	3 "
	16	2 "

S ANTLIÆ, CONT.

Feb.	17	2 A. M.
	19	1 "
	19	midn.
	20	11 P. M.
	21	10 "
	22	10 "
	23	9 "
	24	8 "
	25	8 "
	26	3 A. M.
	27	2 "
	28	1 "
	29	1 "
	29	midn.

S LIBRÆ.

R. A.....$14^h\ 55^m\ 06^s$
Decl.....$- 8°\ 05'$
Period.....$2d\ 07^h\ 51^m$

Feb.	6	4 A. M.
	13	4 "
	20	3 "
	27	3 "

U CORONÆ.

R. A.....$15^h\ 13^m\ 43$
Decl.....$+ 32°\ 03'$
Period.....$3d\ 10^h\ 51^m$

Feb.	7	1 A. M.
	13	11 P. M.
	24	7 A. M.

Phases and Aspects of the Moon.

		Central Time.
First Quarter	Feb. 5	$3^h 39^m$ A. M.
Full Moon	" 12	1 38 P. M.
Apogee	" 17	9 48 A. M.
Last Quarter	" 20	6 15 P. M.
New Moon	" 27	9 47 "
Perigee	" 29	5 48 A. M.

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean. T. h m	IMMERSION. Angle f'm N. P't. c	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration h m
Feb. 5...	13 Tauri	6	11 18	97	12 16	237	0 58
5...	14 Tauri	6	12 05	127	12 43	209	0 38
7...	118 Tauri	6	5 32	38	6 11	294	0 39
7...	125 Tauri	6	12 09	43	12 55	319	0 46
12...	η Leonis	3	5 52	65	6 37	295	0 45
12...	42 Leonis	6	15 38	93	16 38	332	1 00

COMET NOTES.

Two comets are now in view. These are Wolf's periodic comet, which has been observed ever since its discovery by Barnard May 3, and the Tempel-Swift periodic comet found by Barnard, Sept. 27. Three other periodic comets are being searched for, but at latest reports, not yet found. These are: Brooks' 1886 IV, due at perihelion any time from Dec. 1, 1891, to May, 1892; Tempel's due Feb. 28; and Winnecke's due in June, 1892.

The course of the Tempel-Swift comet during January is eastward and southward through the northern part of the constellation Taurus. Jan. 5 and 6 it will be about 3° north of the Pleiades.

Wolf's comet is in the eastern part of the constellation Eridanus, moving slowly and growing fainter. Winnecke's should be found during January and February in the northern part of Virgo and southern part of Coma Berenices. Brooks' 1886 IV, according to Oppenheim's search ephemerides, should be found somewhere near a line passing through Coma Berenices, Virgo, Libra, Scorpio, and Sagittarius.

Search Ephemeris for Comet Brooks, 1886 IV.

(See also Sid. Mess., Dec. 1891, p. 517.)

	Perihelion April 30. R.A. h m	Decl. ° ′	Light.	Perihelion May 30. R.A. h m	Decl. ° ′	Light.
Jan. 21	13 35.2	+ 9 52	0.11			
Jan. 31	13 56.8	7 33	0.18	12 28.6	+ 25 35	0.28
Feb. 10	14 18.4	5 51	0.25	12 36.2	24 35	0.28
Feb. 20	14 39.8	+ 4 15	0.34	12 42.6	+ 24 25	0.39

Ephemeris of the Temple-Swift Periodic Comet.

[From Astr. Nach., No. 3068.]

Paris Midnight.	R.A. h m s	Decl. ° ′	log Δ	Light.
Jan. 1	3 15 04	+ 27 20.1		
2	20 21	27 14.4	9.5408	
3	25 33	27 09.0		
4	30 41	27 03.3	9.5781	4.87
6	40 31	26 51.9		
8	49 54	26 37.9	9.5933	
10	3 58 47	26 24.1		
12	4 07 17	26 10.1	9.6289	3.23
14	15 20	25 55.9		
16	23 03	25 41.6	9.6644	
18	30 24	25 27.4		
20	37 26	25 13.6	9.6996	2.14
22	44 10	24 59.9		
24	50 40	24 46.6	9.7342	
26	4 56 54	24 33.6		
28	5 02 56	+ 24 21.0	9.7681	1.43

Ephemeris of Comet 1891 (Wolf's Periodic Comet).

(Continued from page 516.)

Berlin Midnight.	App. R. A.	App. Decl.	log r	log Δ
	h m s	° ′		
Jan. 2	4 14 34	− 14 05.1		
3	14 42	13 59.1	0.2989	0.0961
4	14 51	13 52.8		
5	15 02	13 46.2	0.3013	0.1044
6	15 15	13 39.4		
7	15 29	13 32.3	0.3037	0.1128
8	15 46	13 25.0		
9	16 03	13 17.5	0.3061	0.1211
10	16 22	13 09.7		
11	16 43	13 01.8	0.3085	0.1294
12	17 06	12 53.6		
13	17 29	12 45.3	0.3108	0.1376
14	17 55	12 36.8		
15	4 18 22	− 12 28.1	0.3132	0.1458

Ephemeris of Winnecke's Periodic Comet.

(From Astr. Nach. No. 3062.)

	App R. A.	App. Decl.	log r	log Δ	$\frac{1}{r^2\Delta^2}$
	h m s	° ′			
Jan. 16	12 31 53	+ 13 57.5			
17	32 47	14 03.1			
18	33 39	9.1	0.3564	0.2227	0.069
19	34 31	15.3			
20	35 23	21.7			
21	36 13	28.5			
22	37 02	35.6	0.3494	0.2020	0.079
23	37 51	42.9			
24	38 39	50.6			
25	39 26	14 58.6			
26	40 11	15 06.9	0.3422	0.1807	0.090
27	40 56	15.5			
28	41 40	24.4			
29	42 23	33.7			
30	43 04	42.3	0.3349	0.1590	0.103
31	43 45	15 52.3			
Feb. 1	44 24	16 03.6			
2	45 02	14.2			
3	45 39	25.2	0.3274	0.1368	0.118
4	46 15	36.6			
5	46 50	16 48.3			
6	47 23	17 00.4			
7	47 55	12.8	0.3197	0.1142	0.136
8	48 26	25.6			
9	48 55	38.9			
10	49 23	17 52.4			
11	49 49	18 06.4	0.3118	0.0913	0.156
12	50 14	20.8			
13	50 37	35.5			
14	50 59	18 50.7			
15	51 19	19 06.2	0.3036	0.0682	0.180
16	51 38	22.2			
17	51 55	38.6			
18	52 10	19 55.3			
19	52 23	20 12.5	0.2953	0.0448	0.209
20	52 34	30.1			
21	52 44	20 48.1			
22	52 51	21 06.5			
23	52 56	25.2	0.2868	0.0214	0.242
24	12 53 00	+ 21 44.4			

	App. R. A.	App. Decl.	log r	log Δ	$\frac{1}{r^2\Delta^2}$
	h m s	° ′			
Feb. 25	12 53 02	+ 22 04.0			
26	53 01	24.0			
27	52 58	44.4	0.2780	9.9981	0.281
28	52 53	23 05.2			
29	12 52 46	+ 23 26.3			

Orbit of Comet *e* 1891 (Barnard Oct. 2). From Barnard's observations of Oct. 2, 6 and 9 as given in the *Astronomical Journal*, Vol. XI, p. 63, I have computed the following elements.

$$T = \text{Nov. } 12.78463$$
$$\pi - \lambda = 268^\circ\ 43'\ 59''$$
$$\lambda = 216\ \ 57\ \ 37$$
$$i = \ \ 77\ \ 27\ \ 42$$
$$\log q = \ 9.98412$$

HARVARD COLLEGE OBSERVATORY, Dec. 4, 1891. O. C. WENDELL.

New Minor Planet No. 321. An asteroid of the 12th magnitude was discovered Nov. 27 by Borrelly at Marseilles. Its position Nov. 27.3808 Gr. M. T. was: R. A. $4^h\ 06^m\ 06.7^s$; Decl. $+ 23^\circ\ 12'\ 58''$. Daily motion, -60^s and $7'$ southward. This is probably No. 321.

Double Shadow of Jupiter's Satellite I. In regard to Mr. Hoffman's observation of the double shadow of Jupiter's Satellite I, reported in the last MESSENGER, permit me to say that I made a similar observation on the evening of Sept. 29, It was in transit nearing egress and it appeared as a white disk against the dark southern equatorial belt; following it was the usual shadow and at an equal distance from this was a second shadow, smaller and not so dark as the true one, and surrounded by a faint penumbra. It would seem to me that there is some intimate connection between this doubling of the shadow of Satellite I, as seen by Mr. Hoffman and myself, and the elongation or doubling of the satellite itself, as seen by Mr. Barnard on Sept. 8, 1890, and Aug. 3, 1891, and which he explains on the supposition of a white belt encircling the equator of the satellite. H. S. HULBERT.

Detroit, Mich.

Companion to the Observatory. This useful little Astronomical Almanac, for such it is, is at hand for 1892. It contains many valuable data not given in the great national almanacs, such as Times of Rising and Setting of the Moon and Longitude of Moon's Terminator, List of Principal Meteor Showers of the Year, Ephemeris for Physical Observations of the Sun, Maxima and Minima of Variable Stars, List of Double Stars suitable for small telescopes, etc. H. C. W.

August Meteors. On the morning of August 11, 1891, between $2^h\ 45^m$ and 3^h, 30 meteors were counted at the Southern Female College, La Grange, Ga., Mrs. I. F. Cox, President. All the meteors were small and white, but few showed trains.

Observing Auroræ. Mr. M. A. Veeder, Lyons, N. Y., has prepared a blank for observing Auroræ, and he invites general co-operation of astronomers and amateur observers in order to collect data for the more complete study of these phenomena. This is certainly important work, and many can aid in it. Send to him for blanks and instructions.

XUM

NEWS AND NOTES.

On further consideration it has seemed best to adopt ASTRONOMY AND ASTRO-PHYSICS as the name of this publication hereafter. On page 96 will be found suggestions and directions to correspondents to which attention is especially called.

In order to give large space to the subject matter of Astro-Physics, a number of articles on General Astronomy are deferred until our next issue. It will be our aim, as heretofore, to bring out as fully as we can, in the future, notices of current work in all branches of astronomy.

It has been strongly urged by some of the earnest amateurs who have been subscribers to the MESSENGER from almost the beginning of its publication, that, in our new departure, we do not forget their wants. They desire and should have notices of work adapted to small instruments, in order to know their field of work well and to contribute to it useful observation. The management of this publication acknowledges heartily and most cordially the large and very generous support which has steadily come to it from amateur astronomers. They shall be remembered, for this publication would not have been what it is, but for their persistent and intelligent aid.

New Naval Observatory.—In his annual report to the chief of the Bureau of Equipment, Navy Department, Capt. McNair, Superintendent of the Naval Observatory submits an estimate of appropriations required for the next fiscal year, as follows:

Approaches and grounds	$11,825
New Meridian Circle	10,000
Three new dwellings for Observers. (Each, $10,000.)	30,000
Repair shop and store house for instruments	4,000
Removal of magnetic instruments and buildings	3,500
Making in all a total of	$59,325.

The appropriation made for the current year was $136,689.

The plea for observers' dwellings on the new Observatory grounds made by the superintendent, though in strong language, is wisely urged.

The report of the Secretary of the Navy for 1891 also contains matter of very general interest to astronomers. This extract will show the tenor of it. Speaking of the New Naval Observatory and the transfer of the astronomical instruments, the Secretary says: "When the transfer and installment of the instruments are completed, the government will be in possession of one of the most admirably equipped observatories in the world. The question of the proper administration of this important charge, representing one of the most important branches of scientific investigation undertaken by the government, is one that demands early attention. The system in existence hitherto, by which the selection of the superintendent has been confined to line officers of the Navy, subject like other officers to changes of duty at comparatively short intervals, prevents that continuity of administration which is essential in carrying on the work of a great national Observatory. No programme of scientific investigation, especially in the department of astronomy, can be carried out successfully by any institution, if liable to frequent interruptions by a change of its administrative head.

"I therefore recommend the adoption of legislation which shall enable the President to appoint, at a sufficient salary, without restriction, from persons

either within or outside of the naval service, the ablest and most accomplished astronomer who can be found for the position of superintendent."

"I would also recommend, in view of the era of progress and scientific development upon which the Observatory is now entering, that an advisory council be organized, composed of the Superintendent of the Observatory and its senior professor and of three other persons of scientific attainments, whose duty it shall be to consider and report upon new instruments and their proper installation; to draw up with such changes as may be necessary, from time to time, the programme of scientific work, including observation, reduction and publication, and to make such inspections and reports as may be desirable in regard to the character of the work done by the Observatory."

This report of the Secretary of the Navy contains the best of official statement of the proper administration of the Naval Observatory that we have ever seen. The recommendations are wise and opportune, and it is to be hoped that this matter will receive the attention of Congress at an early date.

Sirian and Solar Stars. As my prediction that the proper motions of the solar stars would prove to be greater than those of the Sirian stars of the same magnitude seems likely to be verified, I venture to give another consequence of my hypothesis which Professor Pickering's observations go some distance towards confirming. Reverting to my former illustration of a telescope whose range terminates at the average distance of a 12th magnitude star, let me turn it on a part of the sky where there are few, if any, stars at a greater distance than that of an average star of the 11th magnitude. In such a region the telescope will reveal nearly all the stars, and the relative numbers of Sirian and Solar stars will give their true proportions for that part of the sky, the Sirians showing a relative preponderance among the brighter and the Solars among the fainter stars. Let me then turn the same telescope to a region where there is a dense stratum of stars lying further off than the average distance of a 12th magnitude star. A considerable number of the Sirian stars belonging to this stratum will be visible, while few, if any, of the corresponding Solars will be detected. The proportion of Sirian stars will thus appear to exceed the true amount, and the relative preponderance of Sirians will be greatest in the case of the fainter stars. This seems to me to afford the true explanation of the relative preponderance of Sirian stars in the Galaxy. It arises from the greater depth of the stratum of stars, and probably its increasing richness down to the point where the light becomes too faint for spectroscopic observation.

Dublin, Nov. 28. W. H. S. MONCK.

The Lick Observatory and its Work.—From the notice of a late meeting of the Astronomical and Physical Society of Toronto, Canada, published in the *Mail* of Nov. 21, it appears that Mrs. R. A. Proctor gave an illustrated lecture before the society, on the Lick Observatory and its Work. The stereopticon views included those of the great telescope, spectroscope, transit instrument, observatory in Summer, in Winter, in cloud, in sunshine, the offices and cottages of the observers, Mount Hamilton, the approaches to the buildings and views of beautiful scenery in different parts of the mountain taken by Mr. Burnham. It appears that Mrs. Proctor was for several weeks the guest of the professors at the observatory and that she had exceptional privileges in the use of the telescopes. Mrs. Proctor's lecture was heartily enjoyed and highly commended by prominent members of the society.

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Note on the Measurement of Solar Prominences. Two interesting communications have recently been made to the French Academy regarding the aberration of light. In one of these M. Mascart* has done good service in calling attention to the fact that, as yet, we have no direct experimental proof that light travels with the same velocity throughout known space, if we may so denominate the space between us and the most distant of observed stars.

Both Arago and W. Struve were in error, the author points out, in supposing that the invariability of the "aberration constant" from one star to another was sufficient evidence from which to conclude that light travels with invariable speed everywhere in free space, because the difference between the apparent and true direction in which any luminous point is seen depends only upon the ratio of the velocity of light *in the tube of the telescope* to the velocity of the observer.

It might have been added that these velocities are to be measured from any origin of coördinates provided only that this origin is not moving with reference to the medium in which the light is propagated.

All this is strictly analogous to saying that when a sail-boat is just getting under weigh, the apparent change in the quarter from which the wind is blowing depends only upon the velocity of the wind *as it strikes the sail* and upon the velocity of the boat, but not at all upon the source of the wind.

Mascart also calls attention to a remark of Villarceau in which he shows for the first time that the "Constant (?) of aberration" ought to vary from one star to another on account of the motion of the solar system through space. Returning to our nautical analogy, this is equivalent to saying that if one wished to compute the shift of the wind toward the bow of the boat, he would not measure his velocities from a balloon, or from any object floating with the tide, but rather from a fixed buoy.

By this note of Mascart's one's attention is naturally recalled to the other communication by Fizeau,† who after pointing out that the velocities attained by the gases which make up solar prominences are quite comparable to that of the earth in its orbit (30.6 kilometers per second), goes on to remark that:

"Il résulte de ces données que, si une protubérance se développe dans le voisinage de l'ecliptique avec une vitesse de translation de gaz lumineux égale à cette même vitesse de 30.6 km. par seconde, le lieu de la protubérance subira un effet propre, c'est-à-dire un déplacement apparent de $\pm$ 20″.445, lesquelles pourront s'ajouter à l'effet précédent ou s'en retrancher suivant les circonstances de direction, en donnant lieu à des variations correspondantes des distances au bord solaire."

So far as can be seen, the author here neglects the fact that, at any given instant, each point of the solar disk and of the prominence, whether in motion or at rest, is sending to the observer rays all of which are affected by the same correction for aberration. I say the "same" correction since the change in celestial longitude or latitude from one part of the sun's surface to another would affect the aberration quite inappreciably.

If there be relative motion among the parts of the prominence, then since at any instant aberration affects all these parts to the same extent, the prominence will be projected upon the slit of the spectroscope in its true proportions.

If any apology is needed for calling attention to an error of this type it is that the error is one which may for somebody needlessly complicate the study of the solar surface, and is especially misleading when supported by a name of such well-earned distinction as that of Fizeau.

* Comptes Rendus, t. 113, p. 571 (1891).
† Comptes Rendus, t. 113, p. 353 (1891).

In this connection I may perhaps be pardoned for calling attention to still another error, rather insidious, and one to which students unfamiliar with the theory of the grating are especially liable. The only warning against it that I have seen is given by Professor Young (*Sun*, p. 191). The error is this: A micrometer screw in the eye-piece of a spectroscope is sometimes evaluated by looking at the slit directly through the collimator, with the view-telescope. In this way, a revolution of the micrometer head may be determined either in terms of the screw which opens the slit or in angular measure by the transit of a star.

If, now, the instrument be used with a grating to measure the angular height of a prominence, one might very naturally run the micrometer wire from the base to the top of the prominence and apply the *same* micrometer constant which he had just obtained. But such a measure would be very wide of the mark for the reason that a slight variation in the angle of incidence does not produce an equal variation in the angle of diffraction.

This will be seen immediately in differentiating the ordinary equation for the plane reflection grating

$$\sin\theta \pm \sin\gamma = \frac{\varkappa\lambda}{\varepsilon}$$

where θ = angle of diffraction,
γ = angle of incidence,
λ = wave-length at which the prominence is observed,
$\varkappa$ = order of spectrum employed,
ε = grating space.

Here $\frac{\varkappa\lambda}{\varepsilon}$ will be a constant for any given line in any given order, and hence:

$$\frac{d\gamma}{d\theta} = \mp\frac{\cos\theta}{\cos\gamma}$$

$d\gamma$ here, of course, represents the angular width of the slit which just includes the prominence, while $d\theta$ is the *apparent* width as measured by the micrometer eye-piece. The true height of the prominence will therefore be apparently increased or diminished, and in the ratio indicated according as the grating is used so as to make $\theta < \gamma$ or $\theta > \gamma$.

HENRY CREW.

Lunar Eclipse of Nov. 15, 1891. This eclipse was observed at the Boston University Observatory with the 7-inch Clacey refractor, power 100.

Throughout nearly the entire eclipse the sky was clear and the seeing excellent. Near the close the sky became cloudy, and the second external contact could not be observed. The tints upon the Moon during totality were those usually observed, and styled "copper colored," though upon some portions there was a decided brick-red tint, and at times the appearance suggested a blood orange with the outer skin removed.

Several occultations were well determined, but I wish at present to call attention to those only which presented certain striking, although not new phenomena. "Optical illusion" may account for all, but optical illusions are not without cause, and it would seem that the phenomena should, in part, at least, depend upon the angle under which the star approaches the moon's limb.

DM. + 17°.572 approached the limb very obliquely. While skirting the limb, nearly parallel to it, the star was lost for an instant, and, after re-appearing, it seemed to hang upon the edge for about one second, and then to pass on to the face of the moon about four times its own diameter, and to run along still nearly parallel to the limb for about three seconds. All this time the star and the limb were clearly defined. The disappearance at $6^h\ 49^m\ 33^s.4$ W. M. T. was absolutely sudden.

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DM. + 17°.573 approached the Moon at a high angle, seemed to pass upon the limb at a distance about three times its own diameter, without becoming indistinct, and disappeared suddenly at $6^h\ 54^m\ 18^s.5$.

Another star of about the ninth magnitude disappeared in the same manner as the one last named, a very little north of it, at $6^h\ 56^m\ 6^s.7$.

There were other stars whose disappearance was not entered as "sudden," but when a faint star approaches the dimly illuminated Moon it does not seem at all strange that the eye, wearied with watching, should anticipate the contact, and, as a result the star will seem to hang upon the limb of the moon for a short time before disappearing. In the three cases cited above there was nothing to distract in any way the observer's attention, and the apparent movement of the star along upon the Moon's disc was so distinct, especially in the first instance, and the observation so deliberate that, did it not seem to contradict all facts, no one would have thought for a moment of entering the observation as doubtful.

DM. + 17°.564 approached the Moon under about the same angle as DM. + 17°.573, and at near the same point, thus the conditions of the instrument and observer being the same, similar phenomena might have been expected. However the disappearance of 17.564 was absolutely sudden. To be sure it is brighter than 17.573, but its occultation occurred with fully one-half the Moon still clear, and that of 17.573 during totality.

At $6^h\ 23^m\ 16^s.3$ a star that seemed to be moving along a line tangent to the Moon at the north point was lost for a moment near the point of tangency, but soon became distinct again and so remained. The outer curve of the advancing shadow was not observed to present any distinct irregularities of outline save in one instance. At $6^h\ 10^m$ the outline of the shadow seemed to curve *inward* at a point directly eastward from the west point. The eye was removed from the tube and, on returning, the phenomena was none the less distinct, and so continued long enough to be carefully noted. This may be most easily explained by calling it an "optical illusion," but why it should appear at this time and place is not evident. If I remember correctly, I was not, at the time of noticing the inward curvature engaged in examining the outline of the shadow, but the phenomenon was so distinct as to attract the attention.

The stars above referred to were taken from the list in THE SIDEREAL MESSENGER for October, and the identification is believed to be correct, although I have not as yet found time to make the computations necessary to the removal of all doubt, since some stars were observed not given in the list referred to above. The position of the instrument is given in THE MESSENGER for June, 1891. The times were taken from a sidereal chronometer by an assistant, while another made a note of the observations. J. B. C.

Observations of the Partial Phase of the Total Eclipse of the Moon November 15, 1891.—The following observations of the contacts of the shadow with some of the craters were made with the 12-inch equatorial. They are in Mt. Hamilton mean time:

$5^h\ 11.9^m$	Bisection of Tycho.
" 15.6	" " Copernicus.
" 24.3	" " Plato.
" 31.0	" " Manilius.
" 38 5	" " Plinius.
" 39.2	" " Posidonius.
" 51.4	" " Mare Crisium. Somewhat uncertain; that portion of the mare in shadow not seen.
" 52 9	Contact with the preceding end of Mare Crisium.
" 55.9	End of Totality. Pretty fair.

A slight haze and twilight prevented any details being seen in the shadow, though the obscured limb of the Moon was visible during the half phase. There was a slight coloring of red to the portion nearer the middle of the shadow.

MT. HAMILTON, November 15, 1891. E. E. BARNARD.

Disappearance of the New Red Spot on Jupiter; The Great Red Spot and Other Jovian Phenomena. The new oblong red spot which has been visible on Jupiter since last year, on a parallel just south of that of the Great Red Spot, has disappeared.

In THE SIDEREAL MESSENGER for October, p. 413, I have given some account of this object, and the present observations will serve to complete its history.

In the last of October of this year it had attained its maximum distinctness. It was then by far the most conspicuous and striking object on the planet and was of a strong reddish color. It then began to fade rather rapidly, and was scarcely discernible on Nov. 20. On Dec. 14 no trace of it could be seen.

At its maximum it strongly reminded one, in color and intensity, of the Great Red Spot in 1880.

Throughout the past opposition of Jupiter I have carefully observed and measured this singular spot. From these measures, there is no evidence whatever that it changed its latitude during the observations.

Following are micrometer measures with the 12-in. of the distance of the spot from the south and north limbs of Jupiter, reduced to distance 5:20:

Date.	S. Limb.	N. Limb.	Date.	S. Limb.	N. Limb.
	″	″		″	″
1891 July 13	9.5	27.1	1891 Aug. 28	8.8	26.5
25	9.0	27.4	Sept. 16	8.6	26.5
30	8.6	27.0	18	8.8	26.7
Aug. 23	9.0	26.8	Oct. 6	8.7	26.7

On November 20 the spot transitted at $8^h\ 2^m$ Mt. Hamilton mean time, and its corresponding longitude was 119°.9.

The Great Red Spot is gradually becoming more distinct in its form and intense in its color. On Dec. 14 it was strongly marked and quite red. It is now again slackening in its rotation period. During the past opposition its longitude remained quite constant for a number of months at about 3°. (See SID. MESS. for Oct., 1891.) An observation on Dec. 14 made its transit at $5^h\ 5.3^m$ Mt. Hamilton mean time and the resulting longitude = 6.4°. At this observation one of the bright round spots was on the same meridian with the center of the Red Spot and just skirting its south edge.

The remarkable rapidly moving black spots which appeared on the thin faint belt north of the north equatorial band during the past opposition, have ended their existence by forming a new heavy belt from the thin faint one on which they first appeared, an exact repetition of the performance of the black spots which appeared in the same latitude in 1880. The present phenomenon, however, lacked much of the remarkable transformation of 1880. The new belt at the observation of Dec. 14, this year, was identical in appearance with the north equatorial belt.

At the last observation a number of very singular oblong masses were visible stretching across the south polar region in a high south latitude.

MT. HAMILTON, Dec. 15, 1891. E. E. BARNARD.

Peculiar Appearance of Jupiter's Fourth Satellite. On the afternoon of the 12th instant, Satellites III and IV crossed the disc of Jupiter in company; not a

very frequent occurrence. Transit and egress took place at 5:19 and 6:22 W. M. T. respectively. The following reports respecting a peculiarity marking the egress of IV were read at the last meeting of the Astronomical and Physical Society of Toronto. Mr. G. E. Lumsden of Toronto, who observed with a 10¼-inch With mirror, stated that III emerged from the disc without noteworthy feature; that after it was clear he saw IV on the disc near the limb, as an elliptical dark object with a heavily shaded edge towards the planet's center, but that for nearly an hour after egress he could not be positive that he saw IV at all, though he detected certain brownish light, straggling, as it were, between Jupiter and III. Emergence was not observed. The sky was very hazy, but at no time sufficiently so as to entirely obscure planetary detail; the Great Red Spot, though badly defined, was fairly well seen. Satellites I, II, and III were very distinct, yellow in color and of equal brightness. About 7:35 IV was glimpsed as a reddish-brown ball half way between the planet and III and, apparently, at an enormous distance beyond them. Not much difference was detected in the aspect of the moons up to 8:30, when observation ceased. Even at that time IV looked like a satellite, coming out of eclipse,—as a brownish ball. Mr. J. C. Donaldson, LL. D., of Fergus, sixty-five miles north of Toronto, who had a clear sky, wrote: "On coming back to the telescope (a 3½-inch refractor, by Cooke), about 6:35, I fancy I saw that IV had emerged from transit, and I could not help noticing the great contrast in color between it and III and Jupiter itself, IV being of a dark bluish color, apparently so dark, in fact, that when I tried a 2¼-inch glass upon it I could scarcely detect it at all. In the larger glass the sight was very interesting, the two satellites looking almost like a close double-star of complementary colors, III being of a golden yellow, and IV of a dark blue color." In the discussion which followed it was suggested that the bluish color seen by Dr. Donaldson might have been due to the use of a refractor. One of the members was curious to know whether the possible projection of IV against the shadow of III could have had anything to do with the appearance of the former; in other words could IV, as seen from the earth, be brought into contact with III's shadow cone, which was more or less illumined by the planet in front of whose face the shadow fell. G. E. L.

I may say with regard to the above that, as satellite IV had just emerged from transit across the face of the planet, it was between the sun and Jupiter, (the transit of its shadow occurred a few hours later), and, being the outermost satellite, could not possibly come into contact with the shadow of any of the other satellites.

I have in my observing book several notes which indicate the varying color and brightness of this satellite, one on the same night with the observations of Mr. Lumsden and Dr. Donaldson. I will give some account of these next month.

H. C. W.

Dark Transit of Jupiter's Satellite III.—I noticed a dark transit of Jupiter's Satellite III, Dec. 19, at 8:15 P. M., Detroit, (Mich.) local time. The Satellite was intensely black and was closely following the great red spot, but owing to the exceedingly poor definition, I was unable to determine whether it was actually projected on the red spot or not. After egress, the satellite appeared very small and faint, certainly not brighter than 8th magnitude, and of a dull reddish brown color. H. S. H.

Dark Transit of Jupiter's Satellite III. On the evening of Dec. 19, $5^h\ 10^m$ (Central Time), I observed the transit of Satellite III. I anticipated a well-defined bright image but instead there appeared an ill-defined *dark* image which

rapidly grew more distinct, and as its path was on the southern dark belt, the satellite, although plainly seen, was not as clean cut and striking as if it had traversed a lighter back ground. Observation continued during the entire transit. After emergence the full round disk was well shown against the sky, but far less brilliant than any of her other three sisters. Power 300. Lat. 38° 29′; Long. 85° 45′. WILLIS L. BARNES.

Charlestown, Ind.

Solar Parallax.—In No. 3066 of the *Astronomische Nachrichten*, Dr. Auwers has published the results obtained from the heliometer measures made by the German Transit of Venus Expeditions in 1874 and 1882. The stations and measures were as follows:

1874.	Tschifu,	96	measures.	1882.	Hartford,	128	measures.
	Kerguelen Island,	65	"		Aiken,	48	"
	Auckland "	97	"		Bahia Blanca,	112	"
	Mauritius	50	"		Punta Arenas,	158	"

From the 307 measures during the transit of 1874 the resulting parallax comes out 8.873," and, from the 444 measures in 1882, 8.883." Combining these Dr. Auwers gives as the result $\pi = 8.880'' \pm 0.022''$

This result is larger than any other obtained from the transit of 1882, excepting possibly that from the French observations, which we have not at hand at this moment. Professor Harkness obtained from 1475 photographs of the transit of 1882, by the United States Expeditions, $\pi = 8.842'' \pm 0.012''$. From the British observations of contacts Mr. E. J. Stone obtained 8.832", and from the Brazilian observations, Mr. Cruls obtained 8.808". The results from the transit of 1874 ranged from 8.75" to 8.93".

Recently Dr. H. Battermann, at Berlin, has determined the solar parallax from occultations of faint stars by the moon during eclipses and near new moon. He gets from 250 occultations, from April, 1884, to October, 1885, $\pi = 8.794'' \pm 0.016''$. H. C. W.

Diameters of Sun and Venus. In *Astr. Nach.*, No. 3068, Dr. Auwers gives a discussion of the heliometer measures of the diameters of the sun and of Venus, by the German Transit of Venus expeditions. He gets for the diameter of the sun, at its mean distance, 1919.26", from measures by twenty-nine observers. The probable error of this result is ± 0.09". The personal equation of the observers has, however, a wide range, from + 1.03" to − 0.88", so that the mean error of a single measure when those of all observers are combined, is ± 0.69", while that for a single observer is ± 0.49".

The diameter of Venus from seventeen complete measures by 11 observers comes out 63.406" at a distance whose logarithm is 9.422261, or 16.76" at the mean distance of the sun. Applying corrections for personal equation Dr. Auwers gets 16.801" as the most probable value for the diameter of Venus at distance unity. H. C. W.

Dark Structures in the Milky Way. During the last year *Knowledge* has been giving some most excellent full page plates of stellar photographs, by Mr. Barnard of Lick Observatory, Dr. Max Wolf of Heidelberg, and others. Almost every number has contained one or more of these large and beautifully printed plates, showing some interesting regions of the sky, especially in and about the Galaxy. The December issue has a fine specimen, an enlarged photograph taken by Dr. Max Wolf with a Kranz Aplanatic camera of 5¼ inches aperture and a focal length of 30⅛ inches. The exposure-time was $11^h\ 7^m$. The process was

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direct photo-engraving and the region was the Milky Way about ξ Cygni. The interesting tree-like structure in this picture made by adjacent dark spaces is very noticeable.

The Great 40-Inch Telescope. By recent private letter from Messrs. Alvan Clark & Sons, Cambridgeport, Mass., we learn that they have every reason to believe that they will soon be able to begin work on the great 40-inch refractor for southern California. The crown disk is already in hand and it is thought to be the finest piece of glass that these skilful opticians have ever seen. The delay in obtaining the flint disk is due to the unsuccessful attempt of Mr. Mantois of Paris, in moulding it. He has another block ready for firing. Under date of Sept. 10 he wrote as follows:

"Je me suis mis de suité au travail de l'autre bloc dont je vous avais parlé et qui etait reste in arrives. Je vais le pousser avec toute l'activité possible et bientot vous aurez de bonnes nouvelles."

It is the purpose of the Clarks to begin grinding the 40-inch lenses as soon as the flint disk is received. The prisms for the Bruce Photographic Telescope are already well under way.

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